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PROPERTIES AND VALUES OF CERTAIN FISH-NET PRESERVATIVES

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U. S. Bureau of Fisheries

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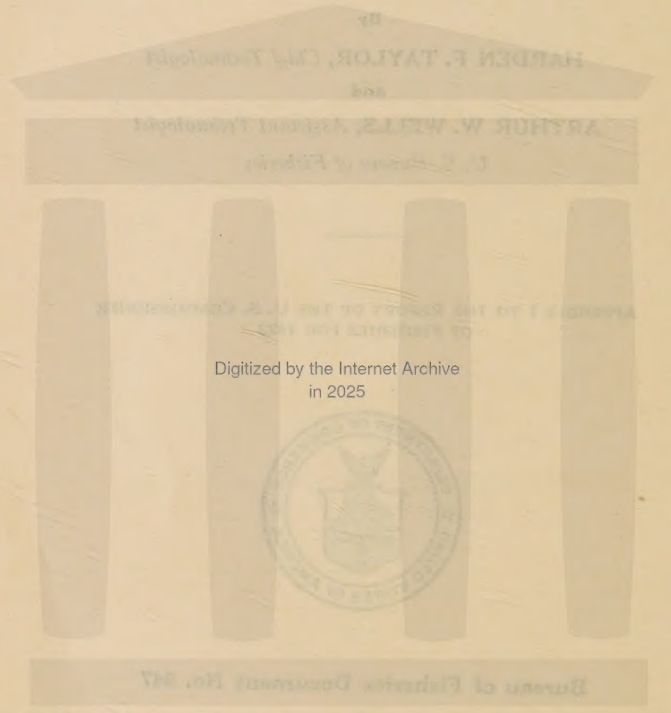

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PROPERTIES AND VALUES OF CERTAIN FISH-NET PRESERVATIVES.[1]

By HARDEN F. TAYLOR, *Chief technologist*, and ARTHUR W. WELLS, *Assistant technologist, U. S. Bureau of Fisheries.*

Contribution from the Fishery Products Laboratory, Washington, D. C.[2]

CONTENTS.

	Page.
Introduction	2
General summary	3
Preliminary experiments	5
Conclusions from preliminary experiments	6
Copper soap	6
Experimental exposure and testing of lines	7
Notation of samples	7
Method of taking samples	9
Series exposed to weather conditions at Washington, D. C	9
Materials tested	9
Tensile strength	10
Summary of results of Washington experiments	12
Series exposed in sea water at Key West, Fla	12
Water conditions at Key West	12
Materials tested	13
Tensile strength	13
Summary of results of Key West experiments	15
Series exposed in sea water at Beaufort, N. C	16
Water conditions at Beaufort	16
Tests with cotton lines	16
Materials tested	16
Tensile strength	17
Flexibility	19
Method of measuring flexibility	20
Results of flexibility tests	23
Resistance to mechanical wear or abrasion (wearing quality)	24
Method of measuring wearing quality	25
Results of wearing tests	25
Resistance to fouling by marine growths	28
Tests with linen lines	29
Materials tested	29
Tensile strength	29
Summary of results of Beaufort experiments	30
Series exposed in sea water at Woods Hole, Mass	31
Water conditions at Woods Hole	31
Tests with cotton lines	32
Materials tested	32
Tensile strength	32
Flexibility	34
Wearing quality	35
Tests with linen lines	36
Materials tested	36
Tensile strength	37
Summary of results of Woods Hole experiments	37

[1] Appendix I to the Report of the U. S. Commissioner of Fisheries for 1923. B. F. Doc. 947.

[2] The Bureau of Standards, Department of Commerce, through its division of textiles, cooperated freely with the Bureau of Fisheries in furnishing and testing the apparatus used for tensile strength, in providing facilities in a room of constant temperature and humidity for making the tests and the measurements of tensile strength, in preparing graphs, and in making valuable suggestions and criticisms.

Experimental exposure and testing of lines—Continued. Page.
Series exposed in fresh water at Put in Bay, Ohio 38
Water conditions at Put in Bay 38
Tests with cotton lines 39
Materials tested 39
Tensile strength 39
Flexibility 40
Wearing quality 41
Tests with linen lines 43
Materials tested 43
Tensile strength 43
Summary of results of Put in Bay experiments 44
Other considerations of importance in judging value of preservatives 45
Varying rate of decomposition of lines in different localities 45
Increase in weight caused by application of preservatives 46
Shrinkage caused by application of preservatives 49
Time and labor required to apply preservatives 51
Color imparted to lines by preservatives 51
Spontaneous heating 52
Apparatus used for testing 52
Linseed oil 53
Copper oleate 53
Other preservatives 54
Effect of heat on cotton lines 54
Discussion of results 54
General consideration of various preservatives in light of data presented 55
Tar 55
Coal tar 56
Pine tar 56
Mixed tar 56
Tanning or barking 56
Quercitron and potassium bichromate 57
The Dutch method 57
Copper paint 58
Petroleum products 58
Gilsonite 59
Copper oleate 59
Chemical properties and manufacture of copper oleate 61
Method of applying copper oleate to nets 62
Grading the several materials as all-round preservatives 63
Tabular summary 68
Bibliography 68

INTRODUCTION.

Most of the fish taken commercially in the waters of the United States are captured by means of textile gear that is perishable—chiefly cotton and linen. The value of the webbing and lines used by our fishermen, as shown in Table 1, is approximately $14,000,000. When this sum is compared with the value of the annual catch of fish, which for the entire nation is about 2,500,000,000 pounds, valued at $80,000,000, it appears that the invested capital for gear is very large; boats, houses, machinery, and the like further increase the cost. Not only is this item for textile gear large, but the gear itself is very perishable. Many nets wear out in one season; perhaps most nets last less than two full seasons. Such rapid loss of invested capital becomes, therefore, of the nature of overhead expense, which helps to diminish the fisherman's reward for his labor, but which must in the end be paid for, at least in part, by the consumer. When considered from the viewpoint of the individual fisherman, a fishing vessel, or company, the importance of reducing the cost of this item is obvious,

but no less obvious is its importance when considered as a part of our national economy.

TABLE 1.—*Number and value of fishing nets in the United States.*

	Number.	Value.[1]		Number.	Value.[1]
Seines	5,440	$1,877,278	Otter trawls	1,287	$74,017
Gill nets	223,890	4,196,592	Paranzella nets	44	9,000
Trammel nets	3,312	116,611	Lampara nets	65	29,500
Pound nets, trap nets, and weirs	17,968	6,355,281	Lines		514,913
Fyke nets	62,570	449,247	Eel pots and traps	23,792	28,695
Stop nets	207	13,367	Lobster pots	247,324	623,475
Hoop nets, pots, and traps	23,047	44,819	Total	608,983	14,337,630
Beam trawls	37	4,835			

[1] These figures, obtained in the regular canvasses of the fisheries, represent not new value but values of the gear owned by the fishermen at the time of the canvass.

One would think, in view of these facts, that the art of preserving nets effectively would already have reached a high degree of perfection, but it has not done so. The literature of the subject is very small; the number of scientific papers reporting serious research into the subject can almost be counted on one's fingers. The conclusions found in the few papers reviewed are mostly inadequate, dealing as they do mainly with the factor of tensile strength and being based on too short periods of exposure. Furthermore, the principal materials used for net preservatives seem to have come into use for insufficient reasons. Tar, the commonest material, appears to be used principally because it is available, cheap, and does some good, though never developed especially to meet any particular requirement, and indeed answering rather poorly most of the requirements of a good all-round preservative. Tanning extracts seem to have come into use through reasoning by a false analogy that if tanning preserves skins it will preserve cotton and linen lines also. As a matter of fact, there is no chemical similarity between cotton or linen and animal skins, and, as will be seen later, very little good results from the use of tanning materials alone on cotton or linen.

The plain need is therefore obvious. The various preservatives now available should be subjected to thoroughgoing scientific investigation to determine their suitability and effectiveness in every way as general or special preservatives, and a serious effort should be made to produce a material that really meets the many requirements of a suitable, efficacious, and all-round preservative of fish nets. The present paper will report results of experiments and tests made during the past two years with these objects in view.

GENERAL SUMMARY.

The principal results and conclusions arrived at and reported in detail in the main part of this paper following are here summarized.

1. The following preservatives and preservative methods were tested: Coal tar, pine tar, coal and pine tar mixed, two proprietary petroleum products, quercitron and potassium bichromate, the Dutch tanning method, copper oleate in nine variations, two proprietary copper paints, a proprietary waterproofing compound, gilsonite (sold

under a trade name), and two combinations of copper oleate and coal tar.

2. The textiles tested were No. 24 cable-laid, hard-finish twine cotton and10-ply linen thread.

3. The factors determined were tensile strength, flexibility, wearing quality, increase in weight, shrinkage, resistance to fouling by marine growths, color imparted, and in some cases liability to spontaneous heating.

4. For determining flexibility and wearing quality machines were devised and made. The construction and operation of these machines are described.

5. Series of lines treated with various preservatives were exposed to weather conditions in the air, in Atlantic Ocean water at three places, and in fresh water at one place.

6. In the series exposed to weather conditions, the deterioration was comparatively slight. Those preservatives with a heavy body, such as the tars and gilsonite, preserved better than did those without heavy body.

7. In the salt water, if preservation of tensile strength only is considered, those samples that contained copper in some form were best preserved.

8. Tar was a fairly good preservative in salt water for about two months, after which time lines treated by it began to lose strength. Coal tar and pine tar were similar in effect, but coal tar was slightly better.

9. Tar, either coal or pine, caused a great increase in stiffness and weight, both of which increases were quantitatively measured. Tar failed to protect nets against fouling by growths of hydroids and barnacles.

10. Tanning by quercitron followed by a treatment with potassium bichromate, without copper, was a poor preservative. Lines treated by this method showed little superiority to untreated lines.

11. Tanning by the Dutch method (quercitron followed by ammoniacal copper sulphate, or bluestone, solution) was much better than quercitron and potassium bichromate. It deposited some copper in the line, preserved fairly well, and increased weight and stiffness only slightly. It was troublesome to apply, caused considerable shrinkage of the line, and was not so good generally as preservatives that deposit more copper in the line. On cotton lines in fresh water it was a good preservative.

12. The proprietary petroleum products and a proprietary gilsonite that were studied showed little value as net preservatives. They increased the weight and stiffness of the line without causing any noticeable preservation. They showed no favorable effect on tensile strength, wearing quality, or resistance to fouling.

13. Copper paint, of which two commercial brands were studied, gave excellent preservation of tensile strength and resisted to a high degree fouling by marine growths; but it excessively increased stiffness and weight of lines to which it was applied, and because of its harshness greatly diminished the resistance of the lines to abrasion or wear.

14. Copper oleate, here tested for the first time and now proposed as a net preservative, showed many valuable characteristics. Dissolved in gasoline and applied it penetrated instantly and dried on

the lines quickly. It preserved tensile strength well in salt water, resisted fouling by marine growths, resisted abrasion or wear as well as any other preservative, increased weight and stiffness only slightly, and imparted an acceptable green color to the line. In fresh water results were less promising. Directions are given for making and using it.

15. Marked differences in the behavior of lines were manifested at different places and in different waters. At Beaufort, N. C., in salt water, sample lines fouled more heavily and disintegrated more rapidly than they did at either Key West, Fla., or at Woods Hole, Mass. In fresh water of Lake Erie, at Put in Bay, Ohio, the sample lines suffered more rapid deterioration than they did at any place in salt water.

16. On linen lines quercitron and potassium bichromate, the Dutch method, a petroleum product, and copper oleate were tested. Copper oleate preserved best in both salt and fresh water. The Dutch method was good; the others were worthless. Linen line, with or without preservatives, and in salt or fresh water, deteriorated more rapidly than cotton lines.

17. In no preservative studied was there detected any tendency toward spontaneous heating or combustion. Such cases of heating of nets as occur must be ascribed to something other than simply the preservative.

18. Even with highly oxidizable oils, such as linseed oil, the temperature necessary to kindle spontaneous heating is in excess of 122° F. (50° C.).

19. Cotton lines exposed to temperature as high as 302° F. (150° C.) dry heat, or 257° F. (125° C.) under steam pressure for two hours showed no significant loss of tensile strength. Higher temperatures than these are necessary to produce any weakening of lines.

20. A mathematical procedure was devised for grading the several materials for all-round usefulness as fish-net preservatives with new white cotton line as a standard of reference. By this method copper oleate easily led all the materials tested as an all-round preservative in salt water.

PRELIMINARY EXPERIMENTS.

In a paper by J. T. Cunningham (1902) mention was made of the successive use of soap and copper sulphate, by which lines were colored a blue green, a method used by French sardine fishermen. This method, which deposits a comparatively insoluble form of copper in the lines, appeared to deserve more attention than it had yet received. Copper is well known to be an exceedingly toxic substance to lower plant life, bacteria, algæ, etc., and highly antagonistic to certain ferments, although comparatively harmless to the higher animals, and therefore seemed a good prospect for trial in different forms. The ferrocyanide of copper is highly insoluble, impermeable to water when dried, and can be applied without difficulty by wetting the lines successively with solutions of copper sulphate and potassium ferrocyanide. Accordingly, in 1920 a small preliminary series of exposures and tests was carried out that included these two treatments—copper soap and copper ferrocyanide. For comparison and control untreated lines were used, and also the

method found in the literature to be best. This latter method, described by Bull (1902) and reviewed by Taylor (1921, p. 22), consists of treating the lines first with a hot solution of quercitron in water, then with a cold solution of potassium bichromate and copper sulphate.

The lines prepared for exposure were treated as follows: (1) Lines treated by Bull's method (quercitron, potassium bichromate, and copper sulphate); (2) a tenth normal solution of copper sulphate followed by a tenth normal solution of potassium ferrocyanide; (3) a tenth normal solution of potassium ferrocyanide followed by a tenth normal solution of copper sulphate; (4) same as (2); but half normal solutions instead of tenth normal solutions were used; (5) a hot solution of soap followed by a hot solution of copper sulphate.

Samples of No. 24 white cable-laid, hard-finish cotton lines were prepared, two by each method, and sent to Beaufort, N. C., for immersion in sea water in June. One sample of each was removed and tested after 4 weeks, the other after 10 weeks. Table 2 shows the tensile strength in kilograms.

TABLE 2.—*Tensile strength of cotton lines exposed in sea water at Beaufort, N. C., 1920.*

Number and method of treatment.	Tensile strength after—	
	4 weeks.	10 weeks.
	Kilograms.	*Kilograms.*
1. Bull's method (quercitron, etc.)	13.40	7.78
2. Tenth normal copper sulphate and tenth normal potassium ferrocyanide	10.86	3.66
3. Tenth normal potassium ferrocyanide and tenth normal copper sulphate	10.62	3.22
4. Half normal copper sulphate and potassium ferrocyanide	13.06	4.98
5. Soap and copper sulphate	11.96	7.32
6. Untreated, control (tensile strength before exposure, 18 kg.)	10.48	1.18

Bull's method was best. Copper ferrocyanide was a failure, for the reason, obvious on examination, that all the copper ferrocyanide was deposited near the surface of the line; the inner parts were not reached. The copper soap preserved nearly as well as Bull's method, though examination revealed the soap to be confined largely to the exterior of the line, and the copper soap itself was a precipitate not uniformly spread over the fibers.

CONCLUSIONS FROM PRELIMINARY EXPERIMENTS.

None of the methods included can be regarded as satisfactory, as a marked decomposition occurs in all of them on 10 weeks' exposure.

Copper ferrocyanide is of little value.

Copper soap promises well and calls for more study to effect good penetration and uniform distribution.

COPPER SOAP.

The green precipitate deposited on the lines by successive applications of soap and bluestone is, of course, copper soap, a mixture of several fatty acid salts of copper oleate, stearate, palmitate, etc. The two principal defects in this mode of application are (1) the

precipitate first formed near the surface of the line prevents further penetration of the reagents, and (2) the precipitate is in the form of irregular particles adhering to the fibers, not enveloping them in a continuous film. It was found that a uniform deposit could be produced and thorough penetration effected if the copper soap were dissolved in a suitable solvent and so applied. Benzol, gasoline, carbon tetrachloride, turpentine, oils, etc., dissolve copper oleate, but not stearate. Accordingly, attention was from this time confined to copper oleate dissolved in benzol, gasoline, kerosene, etc., and in the many experiments with samples of lines preserved copper oleate was included in a variety of concentrations and combinations to determine its value absolutely and in comparison with other preservatives.

Before further experiments were begun, however, it was necessary to solve certain problems connected with the application of copper oleate solutions. It was found that when benzol is used as a solvent the solution in the line creeps to the surface during the evaporation of benzol, so that on the dried line almost all of the copper oleate is on the outside. It was found that a small quantity of mineral oil added to the benzol solution remains and prevents the oleate from creeping. With gasoline the difficulty was scarcely so great, yet it seems wise to add the oil, by which means a perfectly uniform deposit is secured throughout the line.

EXPERIMENTAL EXPOSURE AND TESTING OF LINES.

Four series of experiments were undertaken with a view of determining the effects of the preservatives. Different geographical regions were chosen to determine differences that might arise from that cause; and from time to time new tests were carried out as the need for them appeared and as soon as the technique of applying them could be worked out. These tests will be described as they arise in connection with the experiments. No. 24 cable-laid, hard-finish cotton line was used uniformly throughout for cotton line; for linen line 10-ply salmon gill netting was used. The results are therefore comparable.

NOTATION OF SAMPLES.

In the following key all samples designated by the same letter of the alphabet are always treated with the same preservatives in the same way. In all the results recorded herein the symbols and identifying numbers refer to this key.

Key to symbols for preservatives studied.

COTTON LINES.

A.....White line—untreated—No. 24 medium laid cotton line used as a control.

B.....Copper oleate—7 per cent concentration in gasoline. Lines were dipped into this solution and allowed to become thoroughly saturated. This requires two or three minutes. The lines were then removed and spread out to dry (not piled in a heap).

C.....Copper oleate—7 per cent concentration in gasoline and containing 5 cc. of mineral oil to every 95 cc. of solution and 1–1000 parts of cresol. Applied same as B.

D.....Copper oleate—11 per cent concentration in gasoline. Applied same as B.

E.....Copper oleate—11 per cent concentration in gasoline and containing 2 cc. of mineral oil for every 95 cc. of solution. Applied same as B.

F.....Equal weights of heavy coal tar (sp. gr. about 1.25) and benzol were mixed. The benzol thinned the tar sufficiently, so that no heating was necessary. The lines were then dipped into this tar-benzol solution, soaked for 5 or 10 minutes, and then wound out on a reel to dry. As the lines were drawn out of the tar they were drawn between the fingers in order to remove the excess tar adhering to the lines. This may also be accomplished by using a wringer.

G.....Equal weights of pine tar (sp. gr. 1.18) and benzol were mixed, the benzol serving as a thinner, and thus eliminating the use of heat. Applied same as F.

H.....Coal tar 25 per cent, pine tar 25 per cent, and benzol 50 per cent were mixed and applied same as F.

I.....Quercitron and potassium bichromate. The lines were steeped in a hot solution of quercitron, 1 pound to 2 gallons of water, until the solution was cold, dried, again steeped in the same way and again dried. They were then immersed for a few minutes in a solution of potassium bichromate 3½ pounds to 150 gallons of water. This method was tried for the purpose of comparison with the Dutch method in which tanning extract and copper are used together.

J.....Petroleum product No. 1. This is a product made and sold by a western oil-refining company as a preservative for fish nets. It is a heavy, black liquid, closely resembling tar and is applied in the same way as tar; that is, by dipping once in the cold liquid and then winding on a reel to dry. The product is ready for use as purchased from the manufacturer.

K.....Proprietary waterproofing material. All lines used in experiments with this material were treated at the factory of the concern making the material. The material is a thin, black liquid of specific gravity about 0.850 and is applied by dipping the line into the solution. No heating is necessary.

L.....Dutch method. The lines were steeped in a hot solution of quercitron, 1 pound to 2 gallons of water, until the solution was cold, dried, again steeped in the same way, and again dried. They were then immersed for a few minutes in an ammoniacal solution of copper sulphate, containing 1 pound of copper sulphate and 3 pounds of 25 per cent liquid ammonia for every 12½ gallons of water. For a full description of this method see Olie (1918).

M.....Copper oleate—7½ per cent concentration in gasoline. Applied same as B.

N.....Copper oleate—12½ per cent concentration in gasoline with 5 cc. of mineral oil for every 95 cc. of the copper oleate solution, and 1–1000 parts of cresol. Applied same as B.

O.....Copper oleate—12½ per cent concentration in gasoline. There was no mineral oil added to this. It was run for the purpose of comparison with those combinations of copper oleate solution with oil. Applied same as B.

P.....Copper oleate—12½ per cent concentration in gasoline with 5 cc. of mineral oil to every 95 cc. of copper oleate solution. Applied same as B.

Q.....Copper paint No. 1. This is a red copper paint similar to that used on ships' bottoms. The principal ingredient is copper oxide suspended in some vehicle, such as thin coal tar. The paint was mixed with an equal volume of creosote oil and the line dipped into this solution. The twine was then wound out on a reel. It is preferably used immediately after such treatment, but may be allowed to dry before putting in water.

R.....Copper paint No. 2. This is another red copper paint, similar to Q, but containing more copper. This is applied without any additional thinning, but otherwise the same as Q. The preservative may be allowed to dry or used immediately. The twine was left much stiffer than when treated with copper paint No. 1, and the increase in weight was much greater. More copper was deposited in the line than in the case of Q.

S.....Gilsonite. This is an asphalt product sold by a western company under a proprietary name as a fish-net preservative. It is a thin, black liquid having a specific gravity of about 0.870. The product is sold ready for use and is applied by allowing the line to soak in the liquid for about 20 minutes and then winding out on a reel and allowing to dry.

X.....Petroleum product No. 2. This product is sold by the same concern as was petroleum product No. 1(J). The No. 2 is a black liquid, thinner than No. 1, and intended for use on gill nets and other light gear that must be left flexible. Applied same as J.

Y.....This preservative is a mixture of 50 per cent heavy coal tar (road tar), 35 per cent benzol, and 15 per cent copper oleate (each by weight). Applied same as F.

Z.....The lines are first treated with a 15 per cent solution of copper oleate in gasoline, allowed to dry and then dipped into a solution of coal tar and benzol, 50 per cent each. The lines are then dried as in the case of coal tar (F).
AA....Copper oleate—15 per cent concentration in gasoline. Applied same as B.

LINEN LINES.

T.....Untreated, 10-ply 40, Irish flax salmon thread, used as a control.
U.....Copper oleate—12½ per cent concentration in gasoline. This is the same preservative as was described under P for cotton line and is applied the same as P.
V.....Quercitron and potassium bichromate. This is the same method as was described under I for cotton thread.
W.....Dutch method. This is the same method as was described under L for cotton line.
BB....Petroleum product No. 2. This is the same product as was described under X for cotton line and is applied same as X.
CC.....Copper oleate—15 per cent concentration in gasoline. This is the same solution as was described under AA for cotton line and is applied the same as the other copper oleate solutions; that is, by dipping the twine into the solution and then spreading out to dry.

METHOD OF TAKING SAMPLES.

In order that the same amount of line might be used for each sample, and that shrinkage might be measured, it was necessary to measure the samples under constant tension. To measure a line, one end of the line was made fast at one end of a long hall. The line was then paid out for about 100 feet, passed over a small pulley, and made fast to a 2-kg. weight. The line thus stretched out horizontally under a 2-kg. tension was measured with a steel tape. Trials showed that these measurements could be repeated to within 4 inches for 100-foot lengths. After the samples were treated with the several preservatives they were again measured in the same way as before, and the shrinkage was noted. The figures for shrinkage from all series of experiments will be considered together later (p. 50).

The accurately measured samples were weighed on the analytical balance before and after treatment by the preservatives and the gain in weight recorded. These gains will also be considered together after the several series of experiments have been considered (p. 46). Where the weight per unit length of any particular sample disagreed markedly from the others it was discarded as of over or under size. No doubt the figures contained in this paper show some discrepancies or variations that are due to differences in the line itself, but errors of this kind are reduced to a minimum by obtaining the average of results from numerous tests.

Because of the length of samples needed it was impossible to measure them in a room of constant air conditions. After trials with oven-dried samples for weighing it was found best to weigh in the air-dry condition.

SERIES EXPOSED TO WEATHER CONDITIONS AT WASHINGTON, D. C.

MATERIALS TESTED.

Cotton lines were prepared by each of 11 different preservatives and preservative methods, namely, copper oleate in four different concentrations or combinations, B, C, D, and E; coal tar, F; pine tar, G; the two tars in equal parts, H; quercitron and potassium bichro-

mate, I; petroleum product No. 1, J; a proprietary waterproofing material, K; and the Dutch method, L; untreated white line, A, was used as a control. Seven samples were prepared by each preservative, one to hold as an unexposed check; the other six to be exposed.

These samples were lightly stretched on the roof of the Fishery Products Laboratory, Washington, D. C., on November 25, 1921. At the end of each succeeding month for six months one sample treated by each preservative and one control sample were removed and tested for tensile strength. The experiments made by others in England, Norway, and Holland have usually lasted only about two months. In the present instance it was desired to have a full test of endurance, so the exposures were continued for six months.

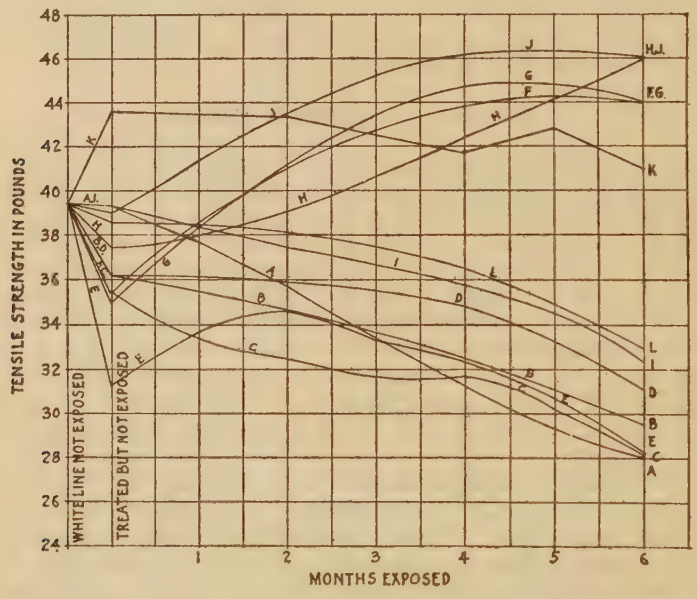

FIG. 1.—Tensile strength of cotton lines exposed to weather conditions at Washington, D. C.

TENSILE STRENGTH.

This factor was measured on a tensile-strength machine at the U. S. Bureau of Standards.[3] The machine was automatic, motor-driven, and recorded the tensile strength by means of a moving pen. Because of variations in the line it is necessary to take the average of a number of tests. The figure given for the control is the average of 60 tests, all others of 15. Table 3 gives the results of the measurements of tensile strength for the lines exposed to weather conditions at Washington, D. C. The same results are expressed graphically in Figure 1, wherein the curves are smoothed by the method of moving averages.

[3] See footnote 2, p. 1.

TABLE 3.—*Tensile strength of cotton lines exposed on roof of Fishery Products Laboratory, Washington, D. C., 1922.*

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Tensile strength in pounds.						
A—White line, untreated control	[1] 39.3	37.3	36.3	33.8	31.4	27.5	28.0
B—Copper oleate 7 per cent in gasoline	36.1	35.3	35.0	34.0	31.9	31.9	29.6
C—Copper oleate 7 per cent in gasoline, 5 per cent oil, 1–1000 cresol	35.5	34.0	33.4	33.2	31.6	31.1	28.2
D—Copper oleate 11 per cent in gasoline	36.1	36.5	36.1	35.3	35.8	34.4	31.1
E—Copper oleate 11 per cent in gasoline, 2 per cent oil	31.4	33.8	33.8	33.2	33.8	31.2	28.4
F—Coal tar 50 per cent, benzol 50 per cent	35.4	43.5	36.9	44.0	46.1	43.1	44.0
G—Pine tar 50 per cent, benzol 50 per cent	35.2	39.6	39.8	44.7	47.0	44.1	44.0
H—Coal tar 25 per cent, pine tar 25 per cent, benzol 50 per cent	37.4	38.2	37.0	41.6	43.3	43.0	46.0
I—Quercitron and potassium bichromate	39.3	40.0	36.6	35.7	36.2	36.6	32.4
J—Petroleum product No. 1	39.0	41.4	44.0	45.7	46.4	47.0	46.0
K—Proprietary waterproofing material	43.7	[2]	43.5	[2]	41.8	42.8	41.0
L—Dutch method	38.6	37.6	39.0	37.6	36.2	36.0	33.0

[1] Average of 60 breaks; every other figure in this table is the average of 15 breaks.
[2] No sample run.

Here, it will be observed, the lines preserved by any of the materials suffer an immediate diminution of strength even before they are exposed. (K, the commercial waterproofing was not tested immediately after treatment.) The reason for this diminution of strength appears to be the lubrication of the fibers. The cotton line used consists of comparatively short fibers that are made to serve the purpose of a long line by being twisted together. The friction between the fibers holds them together. When a pull breaks the line, some of the fibers are actually broken, others disengaged. The introduction of a foreign substance between these fibers or strands may greatly alter the behavior of the line. A lubricant, by diminishing the friction between the fibers, causes more of them to slip out or become disengaged and fewer to break; consequently, the line is weakened. We see that most of our preservatives immediately after application cause such a weakening. These remarks may not, and probably do not, apply to lines made of very long fiber cotton, like sea-island cotton. The tensile strength of such lines is probably the sum of the tensile strengths of the fibers, and binders would have little effect on the tensile strength.

On the other hand, anything between the fibers that increases the friction or glues the fibers together will cause an increase in strength. This effect becomes evident after the material begins to become sticky or dry. In the present instance the lines treated with copper oleate, B, C, D, and E, and by the tanning methods, I and L, on exposure to the weather suffer a gradual though small diminution of strength. At the end of six months' exposure to weather the lines are still strong and useful. These preservatives have no body or binder. The other preservatives that have a body or binder—namely, coal tar, F; pine tar, G; a mixture of the two, H; and the petroleum product No. 1, J—show an increase in strength as the preservative dries. This increase is sufficient to neutralize any deterioration of the fibers. Those preservatives that behave in a similar

way are grouped together in Figure 2, where F, G, H, and J represent all preservatives that have a heavy body, B, C, D, E, I, and L those that have no heavy body, and A untreated line.

SUMMARY OF RESULTS OF WASHINGTON EXPERIMENTS.

1. The effects of exposure of cotton lines to outdoor weather conditions in Washington, D. C., in winter were small; lines so exposed suffered very little deterioration.
2. All preservatives here used caused an immediate small diminution in tensile strength.
3. Preservatives that have a heavy body, such as tar, by binding together the fibers caused an increase in tensile strength after the material became hard and dry.

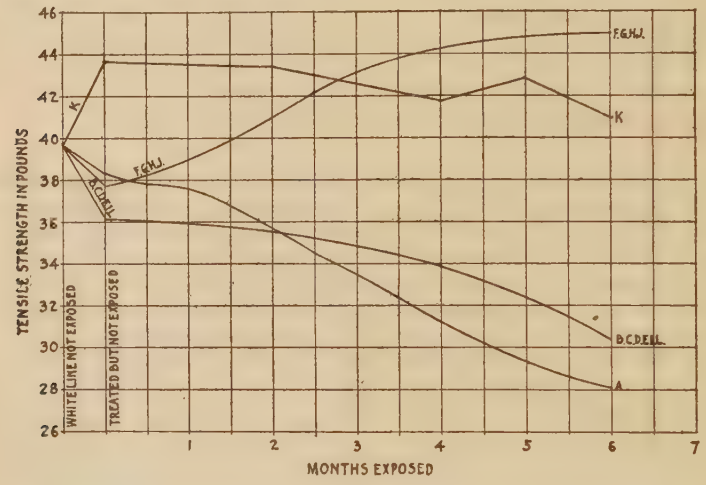

FIG. 2.—Tensile strength of cotton lines exposed to weather conditions at Washington, D. C., grouped.

4. Tar and the petroleum product were adequate and effective preservatives where only weather conditions were encountered.
5. The modifications of copper oleate showed only trifling differences between themselves.

SERIES EXPOSED IN SEA WATER AT KEY WEST, FLA.

WATER CONDITIONS AT KEY WEST.

The sea at Key West is part of the Gulf Stream. The temperature and density of the water during the period the lines were exposed are shown in Table 4. The water is characterized by an abundance of lime. The bottom in this region is covered with a crust of limestone, and a fine white sediment in the water deposits on the articles placed in it. It may be for this reason that the lines did not deteriorate as rapidly as was expected. There were no barnacles or other marine growths on the samples returned.

TABLE 4.—*Water conditions at Key West, Fla.*

Year and month.	Temperature.						Specific gravity.		
	Maximum.		Minimum.		Average.		Maximum.	Minimum.	Average.
1921.	°F.	°C.	°F.	°C.	°F.	°C.			
November	82	28	75	24	79	26.0	1.027	1.020	1.024
December	81	27	68	20	74	23.5	1.029	1.026	1.027
1922.									
January	82	28	63	17	72	22.4	1.030	1.020	1.028
February	82	28	68	20	75	24.0	1.028	1.015	1.022
March	86	30	73	23	80	26.5	1.027	1.025	1.026

MATERIALS TESTED.

In this series 11 preservatives and preservative methods and a control were tested. The preservatives and preservative methods were copper oleate in four variations, B, C, D, and E; coal tar, F; pine tar, G; the two tars in equal parts, H; quercitron and potassium bichromate, I; petroleum product No. 1, J; proprietary waterproofing material, K; and the Dutch method, L.

The samples of No. 24 cotton line, six treated by each method, were fastened to a frame made of galvanized iron pipe and immersed in a cement tide pond at the U. S. Fisheries Station, Key West, Fla., on November 7, 1921. A set of samples was removed every 3 weeks for 18 weeks.

TENSILE STRENGTH.

The samples were tested for tensile strength as already described (p. 10). Table 5 gives the results. These results are shown graphically in Figures 3 and 4, but in Figure 4 those preservatives that give similar results are grouped for easy comparison. In both figures the curves are smoothed by the method of moving averages.

TABLE 5.—*Tensile strength of cotton lines exposed in sea water at Key West, Fla.*

Symbol and treatment.	Unexposed.	Number of weeks exposed.					
		3	6	9	12	15	18
	Tensile strength in pounds.						
A—White line, untreated control	[1] 39.3	37.3	34.3	35.0	29.3	26.2	13.7
B—Copper oleate 7 per cent in gasoline	36.1	34.7	35.1	36.6	35.0	33.4	29.6
C—Copper oleate 7 per cent in gasoline, 5 per cent oil (by volume), 1-1000 cresol	35.5	32.4	41.5	34.5	34.1	35.8	34.5
D—Copper oleate 11 per cent in gasoline	36.1	37.6	37.4	36.6	37.9	37.9	37.9
E—Copper oleate 11 per cent in gasoline, 2 per cent oil	31.4	35.0	33.9	33.5	34.4	34.3	35.4
F—Coal tar 50 per cent, benzol 50 per cent	35.4	43.2	51.0	50.2	47.8	49.6	44.4
G—Pine tar 50 per cent, benzol 50 per cent	35.2	43.9	38.9	44.8	44.2	47.0	41.0
H—Pine and coal tar, 25 per cent each, benzol 50 per cent	37.4	52.2	53.0	44.0	50.1	46.0	51.0
I—Quercitron and potassium bichromate	39.3	36.1	40.6	31.7	25.1	17.6	14.4
J—Petroleum product No. 1	39.0	40.6	34.0	31.0	27.9	19.7	17.0
K—Proprietary waterproofing material	43.7	48.9	42.0	36.6	27.1	20.5	16.2
L—Dutch method	38.6	41.4	41.1	40.7	39.0	36.3	24.4

[1] Average of 60 breaks; every other figure in this table is the average of 15 breaks.

It is apparent, in the first place, that the effect of the sea water at Key West is much more severe than that of the weather at Washington. The untreated line and also those lines treated by quercitron and potassium bichromate, I, petroleum product, J, as well as the proprietary waterproofing material, K, were all but completely rotten in 18 weeks, though a two or three months' test (as was done in the European experiments) would have shown them to

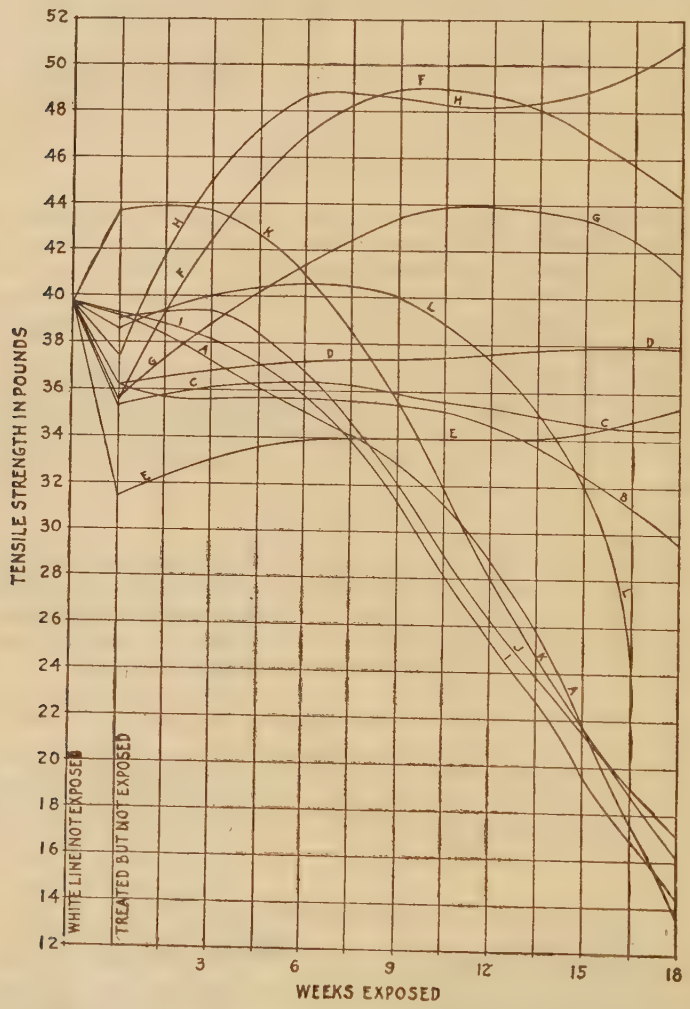

FIG. 3.—Tensile strength of cotton lines exposed in sea water at Key West, Fla.

be good. The Dutch method, L, which deposits a little copper in the lines, was somewhat better, though lines treated by it, too, showed marked deterioration, especially after the fourth month. The only preservative that brought the samples through four and one-half months' exposure unimpaired in tensile strength were the three tars, F, G, H, and the copper oleate, B, C, D, E. The difference between the tar and the copper oleate is that the tar stuck the fibers together,

and thus increased the tensile strength, while the copper oleate did not stick the fibers, but by its preservative action prevented decay and held the lines throughout the test up to their original strength. The lines preserved with copper oleate did not show great differences between themselves, nor do the different kinds of tar show important differences.

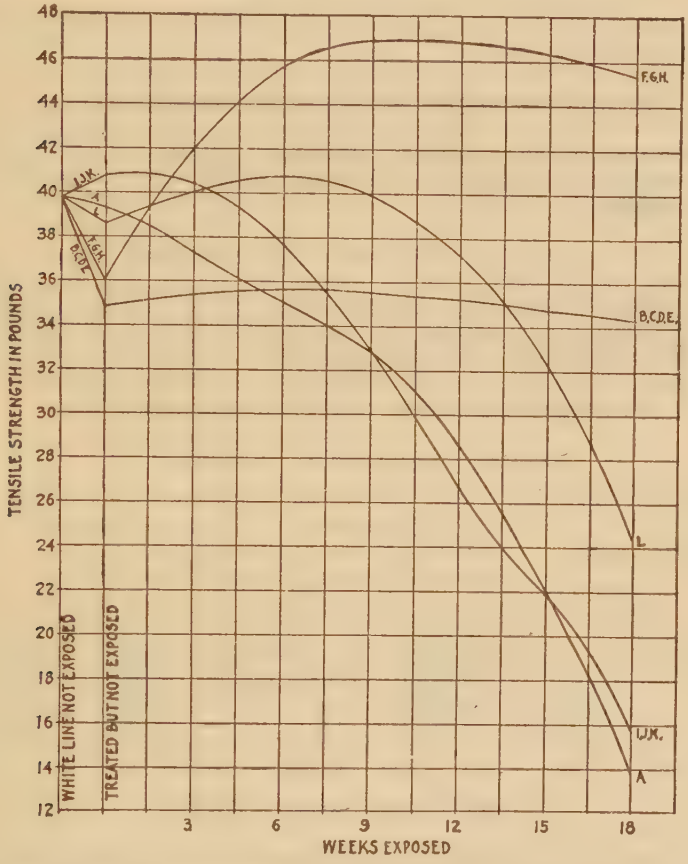

FIG. 4.—Tensile strength of cotton lines exposed in sea water at Key West, Fla., grouped.

SUMMARY OF RESULTS OF KEY WEST EXPERIMENTS.

1. Exposure to sea water at Key West had a severer action on cotton lines than the weather at Washington, D. C.

2. Quercitron and potassium bichromate, petroleum product, and the proprietary waterproofing material showed no noteworthy preserving effect.

3. The Dutch method was somewhat better, though the lines treated by it showed marked deterioration in four and one-half months.

4. The lines preserved with copper oleate showed no substantial deterioration in six months' exposure at Key West; an immediate

diminution in strength after treatment was apparently due to the lubricating effect. The variations of copper oleate showed no considerable differences between themselves.

5. Coal tar, pine tar, and the mixture of the two preserved the tensile strength unimpaired for four and one-half months.

6. The tars also increased the tensile strength by sticking the fibers of the twine together.

7. No growth of marine plants or animals was attached to any of the lines at Key West.

SERIES EXPOSED IN SEA WATER AT BEAUFORT, N. C.

The exposures were made in the water of Beaufort harbor, at the wharf of the U. S. Fisheries Biological Laboratory, from February 15 to August 15, 1922.

WATER CONDITIONS AT BEAUFORT.

The water temperature and salinity for the six months are given in Table 6. Here both salinity and temperature vary more than they do at Key West, the water being at times considerably diluted with fresh water. There is abundant growth of barnacles, hydroids, ascidians, sea anemones, and other attached marine growths.

TABLE 6.—*Water conditions at Beaufort, N. C.*

Year and month.	Temperature.						Specific gravity.		
	Maximum.		Minimum.		Average.		Maximum.	Minimum.	Average.
1922.	°F.	°C.	°F.	°C.	°F.	°C.			
February	60	16	44	7	54	12	1.019	1.015	1.016
March	71	22	52	11	60	16	1.018	1.009	1.015
April	73	23	57	14	68	20	1.023	1.016	1.021
May	80	27	62	17	73	23	1.023	1.018	1.020
June	84	29	73	23	79	26	1.021	1.014	1.018
July	86	30	77	25	82	28	1.022	1.016	1.019
August	82	28	77	25	79	26	1.021	1.014	1.018

TESTS WITH COTTON LINES.

The lines to be exposed were measured and weighed by the methods already described (p. 9). After treatment they were again measured and weighed and differences noted, as shrinkage and increase of weight, respectively. These factors will be considered later. In this series of experiments two new tests were introduced, namely, tests of flexibility and of wearing quality, as influenced by the preservatives. These factors will be discussed in connection with the data obtained concerning them.

MATERIALS TESTED.

The cotton twine used here was, as before, No. 24 cable-laid, hard-finish cotton, in individual samples, each 100 feet long.

The preservatives and preservative methods were as follows: Coal, pine, and mixed tar, F, G, and H, as in the previous experiments; quercitron and potassium bichromate, I; petroleum product

No. 1, J; and also a similar material by new formula by the same company, which we designate petroleum product No. 2, symbolized by X; the Dutch method, L; four variations of copper oleate, M, N, O, and P; two commercial brands of copper paint sold for fish-net preservatives, No. 1, Q and No. 2, R.

TENSILE STRENGTH.

Of the preservatives here considered for the first time the two samples of copper paint cause an immediate increase in the strength of the line. These materials, containing cuprous oxide, suspended in a binding material, cause great internal friction, which manifests itself in its effect on tensile strength and also, as will be seen later, on flexibility and the mechanical wearing quality of the lines. All of the other materials caused the usual diminution of tensile strength by internal lubrication.

The results of tensile strength measurements are given in Table 7. The same results are shown graphically in Figure 5, where the individual preservatives are shown, and in Figure 6, where the preservatives that behave similarly are presented in groups, such groups being the copper paints, copper oleates, and tars.

TABLE 7.—*Tensile strength of cotton lines exposed in sea water at Beaufort, N. C.*

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Tensile strength in pounds.						
A—White line, untreated control	[1] 39.3	33.0	5.3	2.9	[2]	[2]	[2]
F—Coal tar 50 per cent, benzol 50 per cent	35.4	46.0	44.9	36.2	23.2	18.0	[2]
G—Pine tar 50 per cent, benzol 50 per cent	35.2	45.0	46.9	33.8	11.9	3.1	[2]
H—Coal and pine tar, 25 per cent each, benzol 50 per cent	37.4	45.0	46.8	33.9	27.9	16.2	[2]
I—Quercitron and potassium bichromate	39.3	42.4	19.6	3.2	[2]	[2]	[2]
J—Petroleum product No. 1	39.0	40.0	23.4	8.7	[2]	[2]	[2]
L—Dutch method	38.6	40.3	37.0	35.3	20.3	8.3	4.9
M—Copper oleate 7.5 per cent in gasoline	34.2	36.2	36.6	28.6	16.6	11.0	9.7
N—Copper oleate 7.5 per cent in gasoline, 5 per cent oil, 1–1000 cresol	33.2	35.2	33.8	33.9	25.4	20.8	12.0
O—Copper oleate 12.5 per cent in gasoline	33.6	36.6	40.3	30.0	21.3	25.1	8.8
P—Copper oleate 12½ per cent in gasoline, 2 per cent oil	36.3	37.2	39.0	37.0	29.7	19.5	16.9
Q—Copper paint No. 1, 50 per cent creosote oil	41.5	42.0	42.4	40.8	41.0	33.0	18.9
R—Copper paint No. 2	42.7	48.0	50.0	49.5	47.0	40.0	38.3
S—Gilsonite	35.5	28.2	14.5	8.5	3.9	[2]	[2]
X—Petroleum product No. 2	32.9	34.0	5.7	[2]	[2]	[2]	[2]

[1] Average of 60 breaks; every other figure in this table is the average of 15 breaks.
[2] Sample was disintegrated and gone.

Upon exposure the lines Q and R, preserved with copper paint, are easily in the lead, as far as preservation of tensile strength is concerned. At the end of six months' exposure lines preserved by them are nearly as strong as the original untreated line, though a weakening begins to appear in three or four months. Next to those preserved with copper paint, in the diminishing order of tensile strength at the end of six months' exposure, come those treated with the copper oleates, the Dutch method, and the tars. Of these the tarred lines, F, G, and H, made an excellent showing for two months (that is, as long as creosote was present), after which a very rapid deterioration occurred. The establishment on them of a

heavy growth of ascidians or sea squirts broke the lines and carried them away. The Dutch method followed the tars closely, being not quite so good at first, but better at the finish. The lines treated with copper oleate, M, N, O, and P, showed at the beginning the

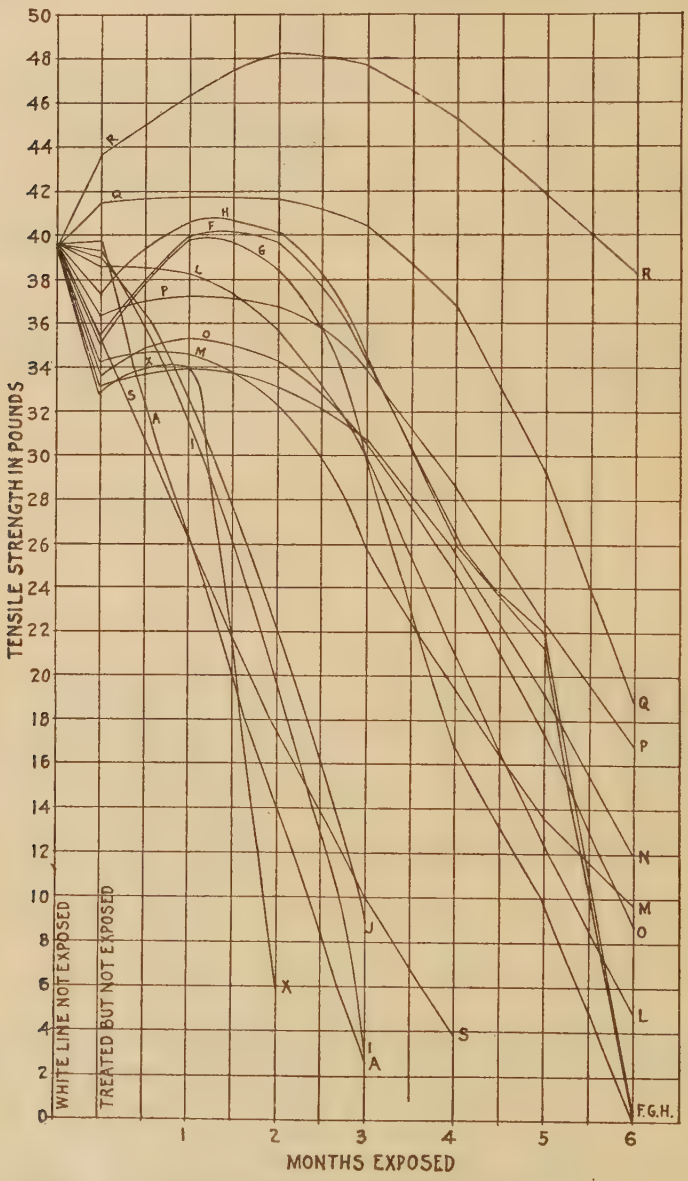

FIG. 5.—Tensile strength of cotton lines exposed in sea water at Beaufort, N. C.

usual weakening due to lubrication, but upon exposure lost strength less rapidly than those preserved by either the Dutch method or tar; in fact, were second only to those treated with the copper paint at the end of six months.

The other preservatives exposed at Beaufort showed no preserving effect worth considering. These were quercitron and potassium bichromate, I; petroleum products, Nos. 1 and 2, J and X; and gilsonite, S. These materials and methods may be definitely eliminated by this experiment, since they do not preserve.

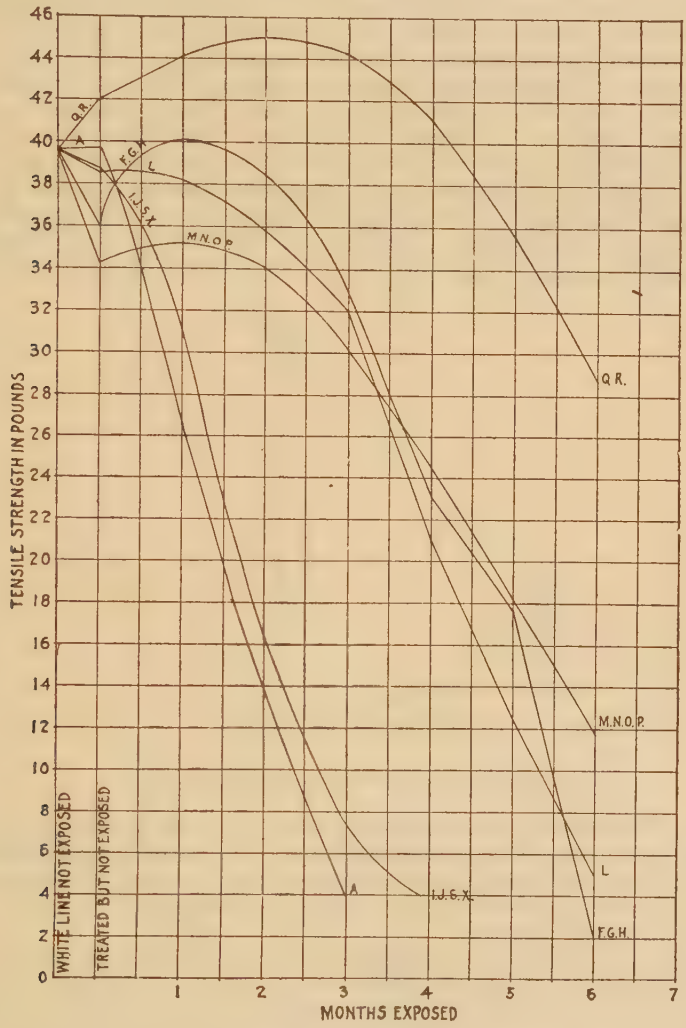

FIG. 6.—Tensile strength of cotton lines exposed in sea water at Beaufort, N. C., grouped.

The results of these experiments show also that lines suffer deterioration much more rapidly at Beaufort than at Key West. This applies equally to untreated lines and to those treated with preservatives.

FLEXIBILITY.

If preservation of tensile strength on exposure were a sure and sufficient criterion, it would now be proper to pronounce copper

paint the best preservative, copper oleate next, then the Dutch method, and finally the tars. Tensile strength, however important it is, is not the only consideration—indeed, in many cases is not the most important consideration.

Flexibility is a factor of great importance in many kinds of fishing textiles. In gill nets a stiff or wiry line will cause the approaching fish to react on coming in contact with the net and to turn and leave, whereas a soft line yields and the fish becomes gilled in his effort to get through. It is also said that a school of fish when surrounded by a purse seine will, upon striking a soft net, continue to exert themselves against it, forcing it outward while the net is being pursed from below. In this manner the entire school is captured; but if the net is stiff and wiry, experienced fishermen say, the fish will react and "sound," or dive, before the seine can be pursed, and thus escape. The factor of flexibility of netting has long been recognized in a qualitative way; but, so far as the writers are aware,

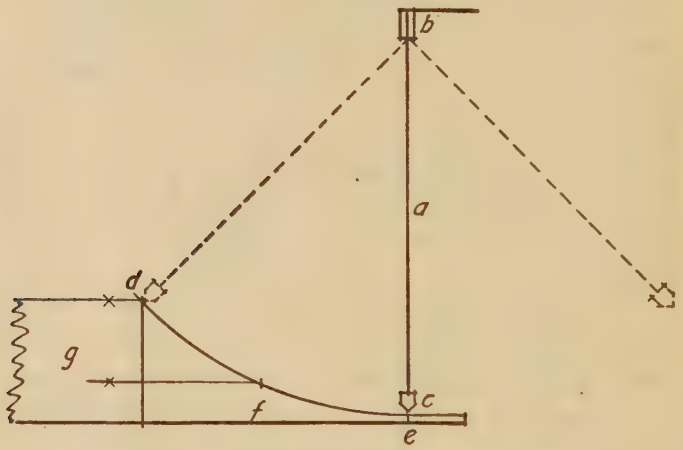

FIG. 7.—Equipment used for testing the flexibility of lines.

no effort has ever been made to measure it quantitatively. The writers have devised a simple method of measuring quantitatively the flexibility of lines treated with various preservatives, and by that means have obtained some highly interesting figures for the several materials studied.

Method of measuring flexibility.—The method consists, essentially, of measuring the energy dissipated (or converted into heat) in bending a sample of the line through a definite angle. For this purpose advantage was taken of the well-known laws of the pendulum. The apparatus consists of a pair of simple wooden jaws, *b*, Figure 7, supported from a horizontal support rod not shown in the figure. A block, *g*, serves as a base, and is cut out as an arc of a circle with the jaws, *b*, as a center, so arranged that a sample of twine gripped in the jaws will just fail to reach when the plummet, *c*, is attached and swings freely. The plummet, *c*, is made of brass and is so constructed that the twine can be gripped straight and true at the center.

The sample of line, *a*, is gripped in the jaws and the plummet attached at the lower end. The plummet is displaced from the

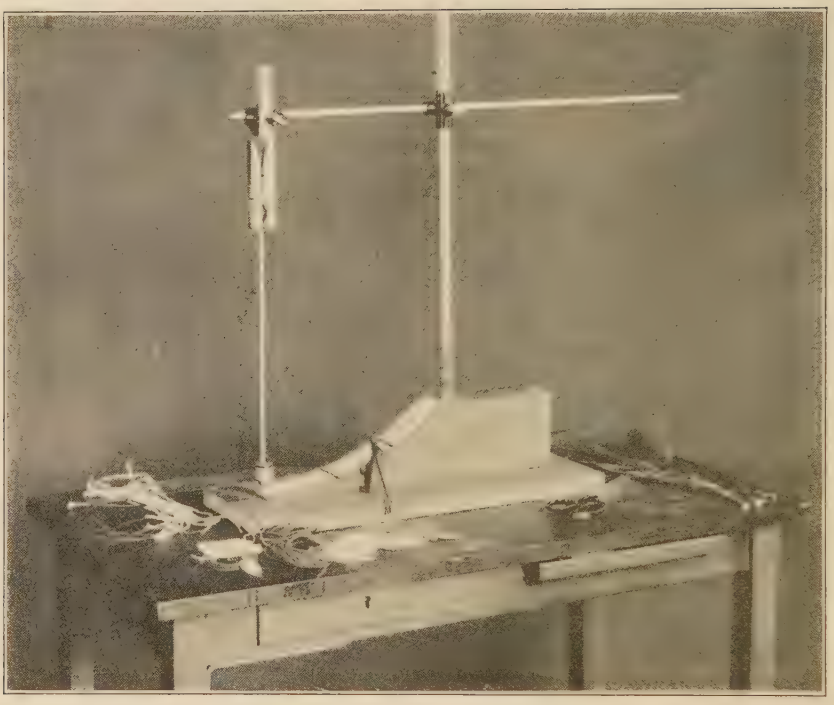

FIG. 8.—Apparatus used for testing the flexibility of lines.

FIG. 9.—Machine used for making wearing tests.

vertical position over *e*, to a convenient point, *d;* that is, so that the pendulum when released will swing through an angle. As the pendulum swings it bends the twine back and forth. The bending of the twine is work and causes the energy originally imparted to the plummet to diminish; that is, the oscillations of the pendulum are of diminishing amplitude. Presently the pendulum will be swinging only to some selected point, *f*, as its highest point. If the oscillations from the start are counted until the pendulum swings only to point *f*, the number will be a measure of the energy that has been transformed in bending the line—the more flexible the sample the greater the number of oscillations necessary to reduce the amplitude to the predetermined angle.

For the present work the following arbitrary standards were adopted as convenient and easily measured: Distance from jaws to arc base, 30 cm.; weight of plummet 50 g.; angle of first oscillation, one radian (57.2958°, or 57°17′45″) or 15 cm. of arc from the vertical position to the starting point, *d;* angle of last oscillation one-half radian (28.6479° or 28°38′52.5″). All the data on flexibility in this paper are obtained on these standards. They are convenient and satisfactory, though there are some grounds for considering a smaller angle of oscillation as a possible improvement. The instrument used in our tests is shown in Figure 8. In the present work the results have been expressed by the number of oscillations necessary to reduce the amplitude by the amount chosen, one-half radian. The actual amount of energy may be calculated in the following way:

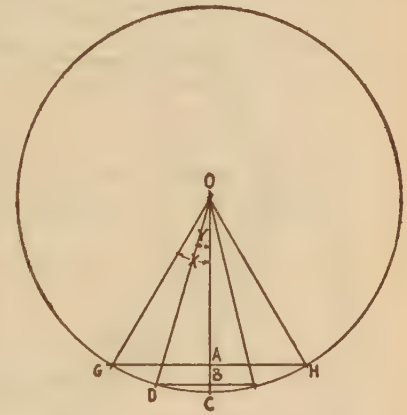

FIG. 10.

When the 50-gram plummet is elevated from *C* to *G*, Figure 10, it receives energy in ergs, equal to its elevation, *AC*, times its mass, in grams, times the force of gravitation. When its amplitude has been reduced so that it rises only to *D* on its upward swing, it possesses energy expressed in the same way, only with the lesser elevation, *BC;* that is, the number of ergs of energy that have disappeared in bending the twine is equal to the difference in elevation times mass, times gravitation, or,

$$\text{Energy consumed} = (OB - OA) \times 50 \times 980$$

to determine $OB - OA$ we determine OB as $r \cos y$ where r is the radius of the circle and y is one-fourth radian, or $14.3239° = 29.07$ and OA as $r \cos x$, where x is one-half radian, or $28.6479° = 26.33$. The difference here is therefore $29.07 - 26.33 = 2.74$ cm. and the energy that has disappeared is $2.74 \times 50 \times 980 = 134{,}260$ ergs. This quantity, being always the same for the different samples as long as we maintain the same standards, we have but to divide it by the number of oscillations to find the average amount of energy transformed in bend-

ing any particular sample one time through the average amplitude, three-fourths radian, or 42.97°. Of course, since each oscillation is of different amplitude, the amount of energy that is transformed with each oscillation is accordingly smaller than that for the preceding, but for practical purposes only the average would be necessary.

It may be objected that the friction of the air is considerable and variable. Efforts were made to determine this source of error, but it was found impracticable to do this precisely, because the angle chosen was too large for the swinging of a frictionless (agate knife-edges) bearing. For this reason a smaller working angle might be better as permitting an accurate determination of the air-friction error. In any case this error is small and practically constant, so that it is not corrected in this paper.

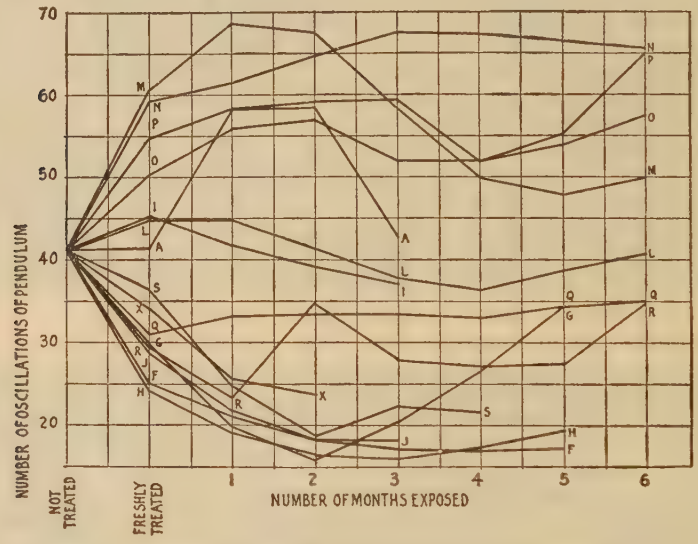

FIG. 11.—Flexibility of cotton lines exposed in sea water at Beaufort, N. C.

Two other sources of error in this test require attention. One is a variation in the flexibility at various places on the sample, the other is a change in flexibility caused by the action of heat, generated by bending, on the viscosity of the preservative. The method of making the test takes these two factors into account. Ten pieces, each about 32 cm. long, were cut from the sample to be tested. One was placed in the jaws of the tester and the number of oscillations counted in the manner described. This test was repeated 10 times at the one place on each test piece, 100 tests being made on each sample. If heating is considerable the successive tests at the same place will show increasing flexibility with preservatives that are subject to variation in flexibility with temperature. Progressive increase in flexibility on repeated bending was found in lines treated with tar, petroleum product No. 1, gilsonite, copper oleate, slight increase in quercitron and potassium bichromate, the Dutch method, petroleum product No. 2, and copper paint No. 2, and no increase at all in copper paint No. 1 and untreated white line.

Results of flexibility tests.—The samples included in the Beaufort series were all tested for flexibility (1) immediately after treatment, and (2) after each month of exposure in the water. In Table 8 and in Figure 11 the results of these tests are given; in Figure 12 the same results are shown by groups of preservatives that had a similar effect on flexibility.

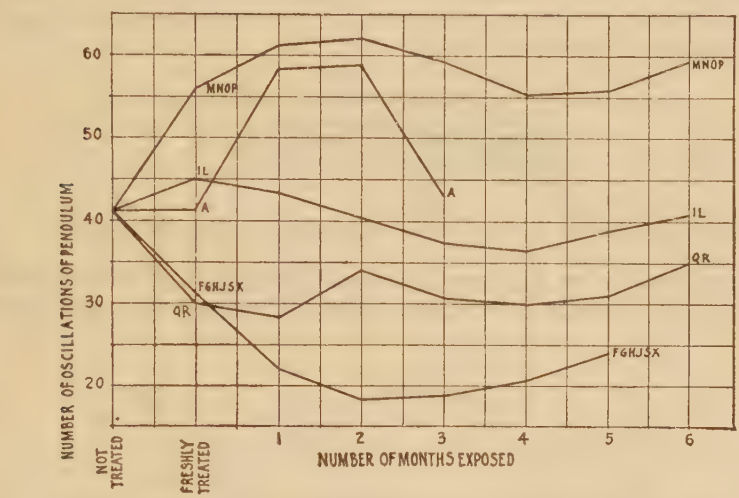

FIG. 12.—Flexibility of cotton lines exposed in sea water at Beaufort, N. C., grouped.

TABLE 8.—*Flexibility of lines exposed to ocean water at Beaufort, N. C.*[1]

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Number of oscillations.						
A—White line, untreated control	41.3	70.6	62.7	43.8	(2)	(2)	(2)
F—Coal tar 50 per cent, benzol 50 per cent	25.0	19.3	18.9	16.6	16.1	18.0	(2)
G—Pine tar 50 per cent, benzol 50 per cent	29.9	15.0	14.8	18.1	27.4	34.2	(2)
H—Pine tar 25 per cent, coal tar 25 per cent, benzol 50 per cent	24.2	18.0	14.8	16.6	16.5	19.2	(2)
I—Quercitron and potassium bichromate	45.1	44.8	35.9	37.0	(2)	(2)	(2)
J—Petroleum product No. 1	29.0	18.2	18.1	18.2	(2)	(2)	(2)
L—Dutch method	44.9	44.3	45.5	33.8	33.6	41.7	40.5
M—Copper oleate 7½ per cent in gasoline	60.5	74.3	71.8	56.6	46.4	46.7	49.7
N—Copper oleate 12½ per cent in gasoline, 5 per cent oil, 1–1000 cresol	59.1	61.4	63.9	68.4	70.1	62.8	65.4
O—Copper oleate 12½ per cent in gasoline	50.2	60.9	56.8	53.0	45.9	58.4	57.3
P—Copper oleate 12½ per cent in gasoline, 2 per cent oil	49.6	64.3	57.5	55.5	64.7	35.3	64.4
Q—Copper paint No. 1	31.1	39.3	29.3	31.0	39.6	28.2	34.6
R—Copper paint No. 2	29.4	14.6	26.4	33.9	23.6	23.3	34.6
S—Gilsonite	36.5	21.1	17.2	18.0	21.3	(2)	(2)
X—Petroleum product No. 1	34.3	18.9	23.5	(2)	(2)	(2)	(2)

[1] Every figure in this table is the average of 100 tests.
[2] Sample was disintegrated and gone.

The most flexible lines after treatment are those treated with copper oleate, M, N, O, and P, which make around 60 oscillations; those treated by the tanning methods—that is, quercitron and potassium bichromate, I, and the Dutch method, L—are next in flexi-

bility, with about 40 oscillations; copper paint, which made such a good showing in the tensile-strength tests, is here at a great disadvantage, the lines being stiff or wiry and making only about 30 oscillations under the conditions described; finally, the tars, petroleum products, and gilsonite cause the greatest stiffening, the lines treated with them making only about 20 oscillations.

According to these tests, if we express the flexibility of tarred lines as 1, then the other preservatives have approximately the following flexibility values:

Petroleum product	1
Gilsonite	1
Copper paints	1½
Tanning methods	2
Copper oleate	3

RESISTANCE TO MECHANICAL WEAR OR ABRASION (WEARING QUALITY).

In experiments so far presented and discussed, the undesirable changes in the lines were brought about during exposure principally

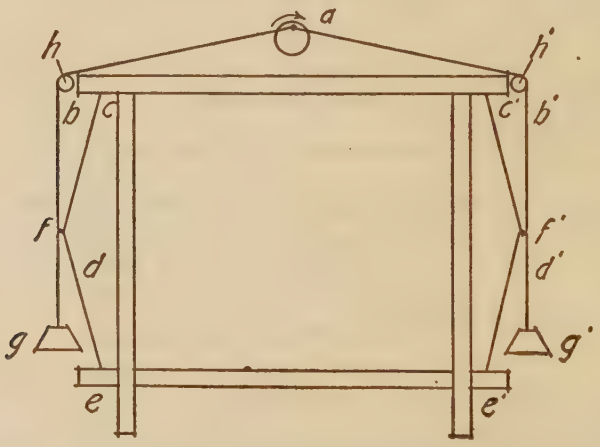

FIG. 13.—Apparatus used for testing the wearing quality of lines.

by decomposition or weakening of the lines, presumably by chemical or biological agencies. These agencies are, perhaps, not always the greatest enemy of lines. It has been shown that in air and exposed to the weather cotton lines do not undergo rapid deterioration. Many types of nets are actually in the water only a small part of the time. They are handled much, however, are dragged over the gunwales of boats and across decks and wharves, and the lines rub against themselves during such handling. No doubt this factor of mechanical wear or abrasion is highly important in such gear as purse seines, haul or drag seines, and trawls. It is to be expected, also, that the preservatives used will have an important bearing on this factor. Like flexibility, it has often been recognized qualitatively as a factor, but has never been given quantitative measurement or expression. In the present work the attempt was made to measure the wearing quality of the lines treated.

Method of measuring wearing quality.—The principle of the method is the obvious one, which consists of drawing or "sawing" the lines across some wearing or abrading edge under a constant pull and measuring the number of strokes required to wear it out. In practice, however, this proved to be difficult of application. Close-grained wood was tried first, but the results were not at all consistent or even similar for similar samples. It was found that the edge wore sleek at a very inconstant rate. With iron, steel, hard rubber, and even glass the same difficulties were encountered. The most satisfactory results were obtained by causing the sample to saw against itself at a rather acute angle and under pull of a definite weight.

The construction and operation of the machine for making this test is shown diagrammatically in Figure 13. To an eccentric, *a*, are fastened the lines to be tested, *b* and *b'*, which are passed over the rollers, *h* and *h'*, and fastened at *c* and *c'*. Other pieces of the same line, *d* and *d'*, are made fast at *e* and *e'*, and run through the slack part of *b* and *b'*, at *f* and *f'*. The samples so attached form angles *cfh* and *efg*, etc., of about 13°. Weights of 1 kg. (*g* and *g'*) are attached to the free ends of the lower piece of line. The eccentric *a* is revolved by a motor, imparting a reciprocating motion to the samples *b* and *b'*, which causes them to saw across similar samples, *d* and *d'*. The samples thus wear out and the weights drop to the floor. The number of strokes necessary to wear each sample down to a breaking strength of 1 kg. is taken as a measure of the wearing quality. The machine was made so as to run 10 samples at a time, five on each side of the table, and a mechanical revolution counter was used to assist in keeping count. In Figure 9 (p. 21), the machine used is shown with all samples in, ready to start.

TABLE 9.—*Wearing quality of cotton lines exposed in sea water at Beaufort, N. C.*

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Number of strokes.						
A—White line, untreated control	[1] 399.0	56.8	(2)	(2)	(2)	(2)	(2)
F—Coal tar 50 per cent, benzol 50 per cent	189.4	172.4	94.5	103.9	34.4	14.9	(2)
G—Pine tar 50 per cent, benzol 50 per cent	159.7	141.4	97.8	75.1	5.7	(2)	(2)
H—Pine tar and coal tar 25 per cent each, benzol 50 per cent	168.5	171.6	107.2	92.6	43.6	9.8	(2)
I—Quercitron and potassium bichromate	50.9	45.1	(2)	(2)	(2)	(2)	(2)
J—Petroleum product No. 1	281.3	124.2	17.0	(2)	(2)	(2)	(2)
L—Dutch method	46.6	84.6	79.6	91.0	8.8	0	0
M—Copper oleate 7½ per cent in gasoline	118.4	167.4	141.2	129.2	12.8	8.1	6.1
N—Copper oleate 12½ per cent in gasoline, oil 5 per cent, cresol 1–1000	127.5	157.3	117.0	150.9	79.4	42.8	22.8
O—Copper oleate 12½ per cent in gasoline	191.1	191.9	143.6	123.3	40.4	48.1	5.1
P—Copper oleate 12½ per cent in gasoline, 2 per cent oil	141.7	228.8	157.4	182.4	122.0	13.2	41.5
Q—Copper paint No. 1 plus 50 per cent creosote oil	23.0	57.4	43.6	58.7	56.7	34.2	11.6
R—Copper paint No. 2	89.0	30.8	17.0	17.9	12.5	14.1	14.0
S—Gilsonite	280.0	207.4	24.4	(2)	(2)	(2)	(2)
X—Petroleum product No. 2	132.0	31.8	1.8	(2)	(2)	(2)	(2)

[1] Average of 100 tests; every other figure in this table is the average of 50 tests.
[2] Line was disintegrated and gone.

Results of wearing tests.—This method of making the mechanical wearing tests on the various samples exposed and tested, though good enough for use and having already given some valuable data,

is still not all that one could wish. It is an extremely severe test, and no line that is seriously impaired in strength by exposure endures more than a few strokes. Linen line will not endure more than half a dozen strokes. The results it gives are influenced considerably by tensile strength, though other factors also enter. Because of a rather wide variation 50 tests (five sets on the machine) were made on each sample, and the figures here given are the averages, respectively, of 50 tests. The lines were dry when tested. These results, which are somewhat surprising, are shown in Table 9 and graphically in Figures 14 and 15.

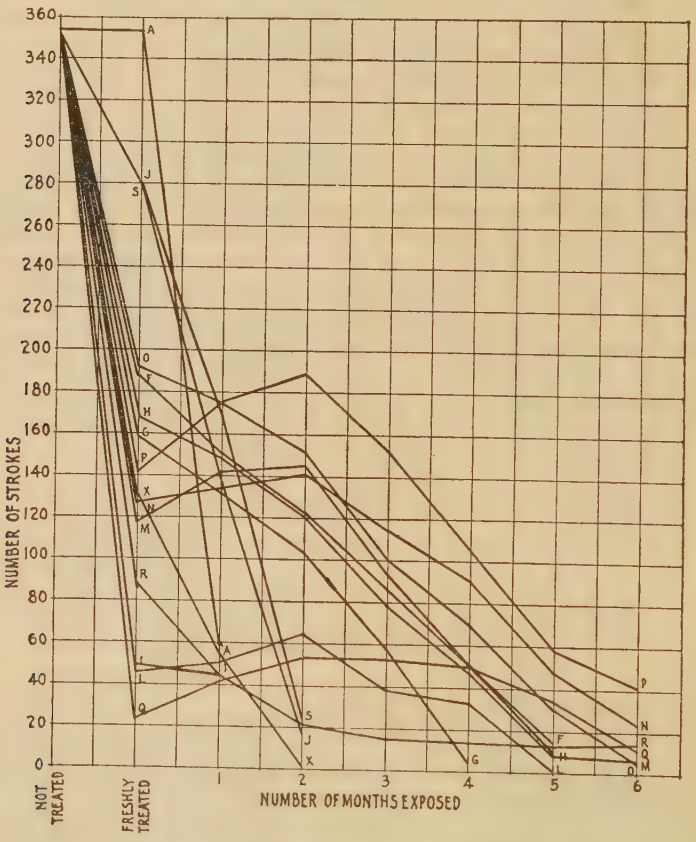

FIG. 14.—Wearing quality of cotton lines exposed in sea water at Beaufort, N. C.

Among the points worthy of note are the following: Of the fresh unexposed lines the untreated line, A, wore best of all. Any preservative tried immediately diminished the wearing ability in the following increasing order: The petroleum product No. 1, J, and gilsonite, S, reduced the wearing quality least; the three tars, F, G, and H, reduced it more; the copper oleates, M, N, O, and P (O showing an apparently anomalous wearing quality), reduced it yet more; and finally a group very low in wearing ability, consisting of all the others, namely, the copper paints, Q and R, quercitron and potassium bichromate, I, and the Dutch method, L, reduced it most of all. It

should be noted that the tarry preservatives, or others having a protective body, do have the property attributed to them of protecting against chafing or wearing.

Upon exposure, however, the relative wearing abilities rapidly change. The untreated line, A, and lines treated by the petroleum products J and X, gilsonite, S, and quercitron and potassium bichromate, I, all rapidly lose wearing quality so that in two months it is practically zero. Lines treated with the copper paints, Q and R, never have much wearing ability, even when freshly treated. Yet,

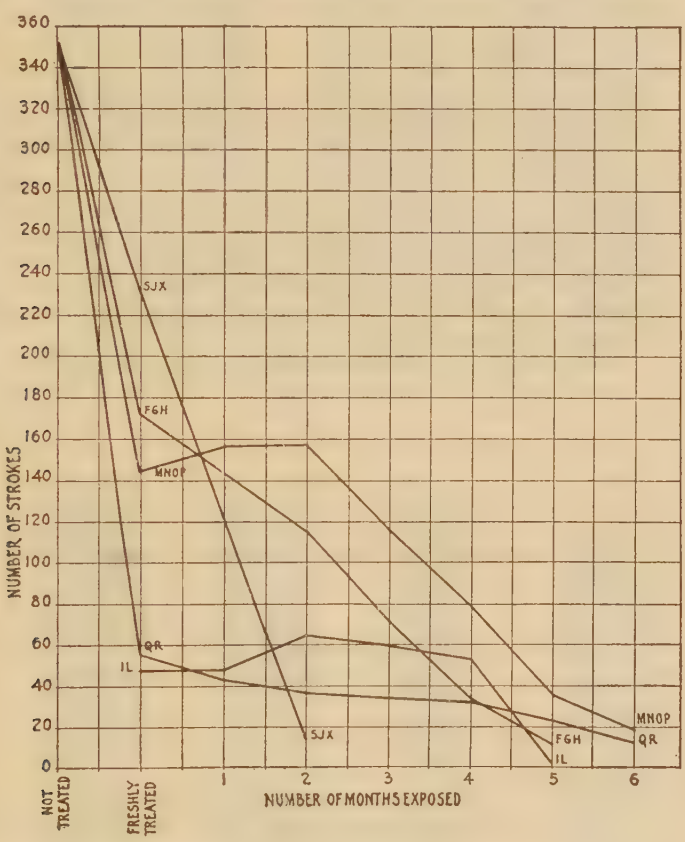

FIG. 15.—Wearing quality of cotton lines exposedi n sea water at Beaufort, N. C., grouped.

because decomposition of the line is so well prevented and tensile strength so well preserved, such wearing quality as they have persists well through the full six months. The tarred lines do fairly well but suffer a steady decline in wearing quality. Lines preserved with copper oleate lead all others after the first month. This material is waxy or soapy and seems to possess physical properties that enable a line treated by it to rub without giving up its fibers. The harshness of copper paint and of the tanning extracts also is easily palpable and shows up clearly in the results. The conclusions from this test are plainly that (1) all preservatives studied cause an immediate

diminution of wearing quality as compared with new white line in the dry condition, (2) copper paints, which give such good results with tensile strength tests, are very poor in their resistance to mechanical wear, and (3) copper oleate leads all the preservatives in mechanical wearing ability upon exposure.

It is obvious that this factor is highly important in the selection of a proper preservative. The test described may or may not simulate closely the wear that nets receive while in use. Nevertheless, it is mechanical wear and brings out marked and unexpected differences in the several preservatives. It is therefore believed to be of value as a test.

RESISTANCE TO FOULING BY MARINE GROWTHS.

When nets remain in water for a long time, as pound nets, traps, etc., must, they are subject to fouling by growths by barnacles, hydroids, ascidians, algæ, etc. These organisms are objectionable for several reasons. Barnacles injure the fisherman's hands and make handling the net difficult; fouling growths cause the nets to resist current and tides, which accordingly causes greater strains on the nets. The weight of the fouling may many times over exceed the weight of the net and therefore greatly increase the strain on it. It is a desirable characteristic of net preservatives that they prevent the accumulation of these growths.

At Key West, Fla., no noticeable fouling appeared on any of the lines. At Beaufort, N. C., however, fouling proved to be an important consideration. Figures 16, 17, 18, and 19 show the samples of cotton and linen lines that were returned from Beaufort at the end of four months before they were subjected to tests. The key to these is as follows: All of these samples were prepared at the same time, were placed in the water at the same time and place, and were taken up at the end of four months, with the exception of X, which was in the water only one month.

Symbol and treatment.	Condition after four months in water.
A—White line; no treatment	Disintegrated and gone.
F—Coal tar	Fouled with hydroids and barnacles.
G—Pine tar	Do.
H—Pine and coal tar	Do
I—Quercitron and potassium bichromate.	Covered with dense matting of hydroids.
J—Petroleum product No. 1	Do.
L—Dutch method	Few hydroids; nearly clean.
M, N, O, P—Copper oleate	Substantially clean; very few barnacles; no hydroids.
Q, R—Copper paints	Perfectly clean; no growths.
S—Gilsonite	Fouled with hydroids and barnacles.
X—Petroleum product No. 2	Fouled, less than petroleum product No. 1. This sample had been in water only one month.
U—Copper oleate	Slightly fouled; some hydroids; no barnacles.
W—Dutch method	Do.

All the lines that resisted all fouling growths contained copper; that is, those treated with the copper paints, Q and R, and the four copper oleates, M, N, O, and P. The Dutch method, L, containing a very small quantity of copper, was fouled only slightly. All the others that contained no copper fouled to an objectionable degree, especially quercitron and potassium bichromate, I, and the petroleum

FIG. 16.—Cotton lines exposed in sea water at Beaufort, N. C., for four months. Heavily fouled. J, petroleum product No. 1; I, quercitron and potassium bichromate.

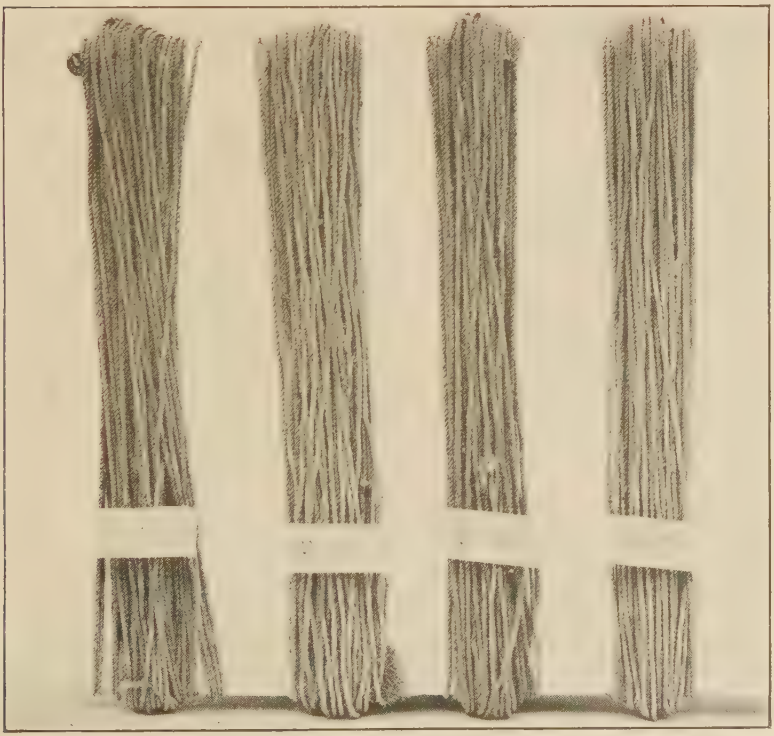

FIG. 17.—Cotton lines exposed in sea water at Beaufort, N. C., for four months. No fouling. All had been treated with copper oleate.

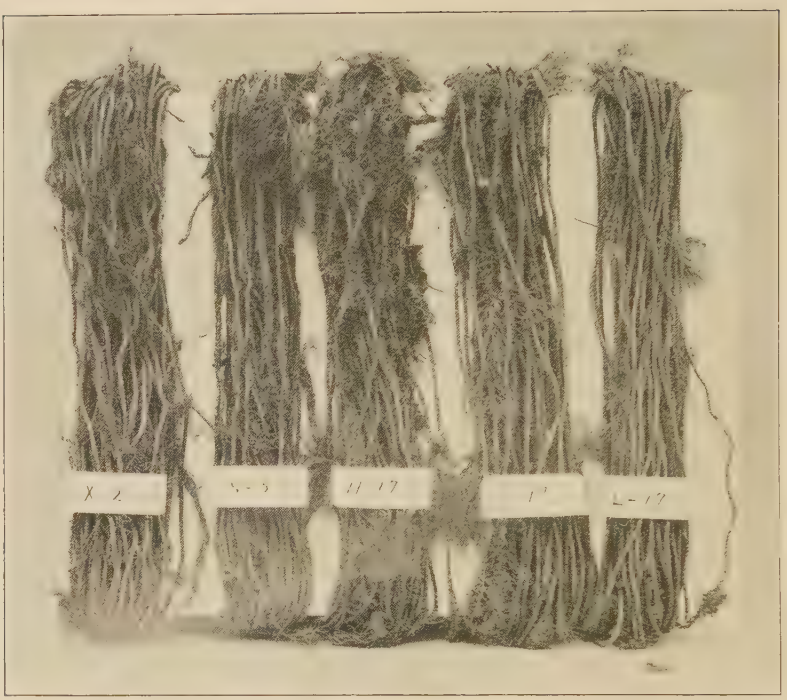

FIG. 18.—Cotton lines exposed in sea water at Beaufort, N. C. X, petroleum product No. 2, exposed one month; all the rest exposed four months. S, gilsonite; H, pine and coal tar; G, pine tar; L, Dutch method. All were somewhat fouled.

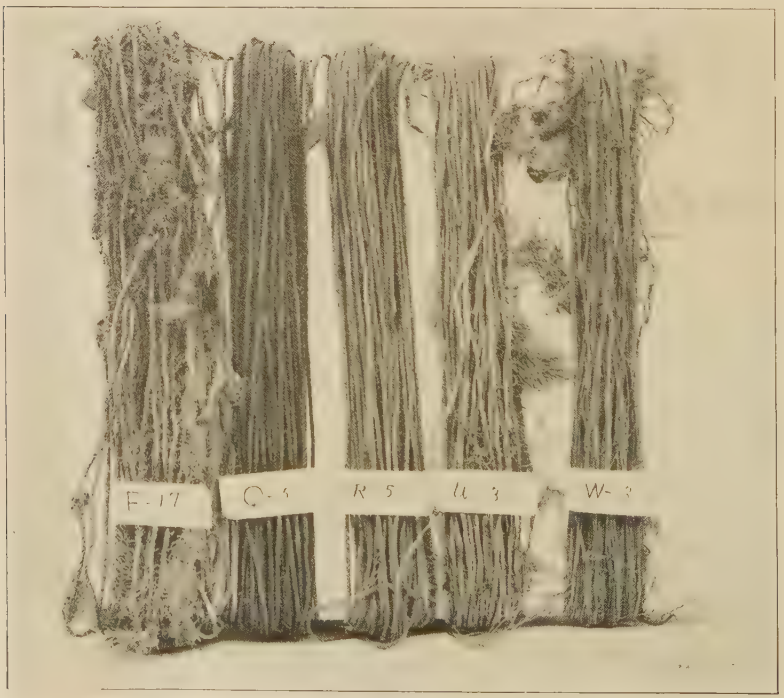

FIG. 19.—Three cotton and two linen lines exposed in sea water at Beaufort, N. C., for four months. F, coal tar on cotton, heavily fouled; Q, copper paint No. 1 on cotton and R, copper paint No. 2 on cotton, no fouling; U, copper oleate on linen and W, Dutch method on linen, both somewhat fouled.

product, J, lines treated with which are almost entirely covered with hydroids. The tarred lines are also heavily fouled. In the next two months after these samples were taken up the tarred samples were so heavily fouled with ascidians that they broke and were carried away. The lines treated by quercitron and potassium bichromate, I, petroleum products Nos. 1 and 2, J and X, and gilsonite, S, also failed to be returned.

Here, again, copper oleate shows to advantage, though no better with respect to prevention of fouling than copper paint. The petroleum products, gilsonite, quercitron and potassium bichromate, and the tars seem to produce an agreeable anchorage for these organisms, and this fact must be held seriously against them as net preservatives.

TESTS WITH LINEN LINES.

MATERIALS TESTED.

In this series of experiments samples of linen lines were included. The linen selected was 10-ply 40 "Irish flax salmon thread," loose-laid, such as is used in gill netting for salmon on the Pacific coast. The tensile strength of the untreated, unexposed line is 55.2 pounds, somewhat greater than that of No. 24 cotton twine. Although its tensile strength is greater than cotton, it is a characteristic of this linen line that it fails completely to resist mechanical wear on the testing machines, even the new untreated line falling in two in only a half dozen strokes. The exposed samples usually broke on the first stroke, so that it was useless to apply this test. This weakness is apparently due, at least in part, to the fact that the component strands of the line are not twisted together, but each acts separately. When the lines "saw" together, each individual strand is exposed; under such circumstances the life of the whole line is only equal to the life of one strand.

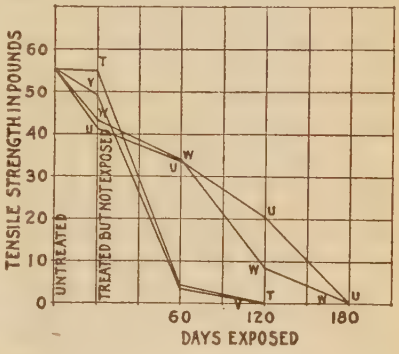

FIG. 20.—Tensile strength of linen lines exposed in sea water at Beaufort, N. C.

It would be useless to test for linen thread the preservatives that cause stiffness, such as tar, copper paint, and gilsonite. The preservatives and preservative methods physically suitable for gill nets and available at the beginning of these Beaufort experiments were three, quercitron and potassium bichromate, V (when applied to linen this symbol was given), Dutch method, W, copper oleate, U, the untreated linen, T, being the control. The samples were exposed at Beaufort 180 days, samples being returned each two months. The exposure began February 15 and continued to August 15, 1922.

TENSILE STRENGTH.

The results of the measurements of tensile strength of these samples are given in Table 10 and are shown graphically in Figure 20.

TABLE 10.—*Tensile strength of linen lines exposed to sea water at Beaufort, N. C.*

Symbol and treatment.	Unexposed.	Number of months exposed.		
		2	4	6
	Tensile strength in pounds.			
T—Untreated control	[1] 55.2	4.2	[2]	[2]
U—Copper oleate solution 12½ per cent in gasoline, 5 per cent oil	41.3	33.9	18.9	[2]
V—Quercitron and potassium bichromate	49.5	3.2	[2]	[2]
W—Dutch method	43.0	34.3	7.8	[2]

[1] Average of 50 breaks; every other figure in this table is the average of 15 breaks.
[2] Line was disintegrated and gone.

The conclusions from these tests are obvious: Linen lines, with or without preservatives, disintegrate more rapidly than cotton lines under the same conditions in salt water at Beaufort, all four samples having disappeared before the term of six months expired. Only the two samples that contained copper—that is, copper oleate, U, and the Dutch method, W—lasted four months, the one preserved by the Dutch method being then all but totally rotten. At the end of two months the lines treated by either the copper oleate or Dutch method are still serviceable, but the leading score in this experiment easily belongs to copper oleate.

The principal method of preserving these linen lines on the Pacific coast is barking—that is, treating with the hot extract of oak bark—which treatment is not followed by a mordant. Even when mordanted, as in quercitron and potassium bichromate, it is plain that no good results are obtained by the use of bark, unless possibly the periodical treatment with the infusion merely washes and sterilizes the net for the time being. When bark is mordanted with ammoniacal copper sulphate (Dutch method), considerable good is done; but this method is much more laborious and time-consuming than the application of copper oleate and not so effective. Washing the nets in bluestone (copper sulphate) solution, as done on the Pacific coast, may serve to keep the lines clean, but because of its solubility bluestone can not be a permanent preservative. The regular use of copper oleate in the salmon gill-net fishery should effect a marked saving in nets.

SUMMARY OF RESULTS OF BEAUFORT EXPERIMENTS.

1. The materials and preservative methods studied at Beaufort were: For cotton lines, copper oleate in four variations, coal tar, pine tar, coal tar and pine tar mixed, quercitron and potassium bichromate, petroleum products Nos. 1 and 2, Dutch method, copper paints, Nos. 1 and 2, and gilsonite; for linen lines, quercitron and potassium bichromate, Dutch method, and copper oleate, 12½ per cent solution.

2. In the preservation of tensile strength of cotton lines the copper paints, which contain heavy concentrations of copper, excelled. Copper oleate, in the concentrations tried, which were much less than those of copper paint, was next in order of superiority; the Dutch method, also containing copper, was third; the tars were fourth; all

the other preservatives failed to bring their respective lines through six months' exposure.

3. The effects of sea water at Beaufort were more severe than those at Key West, Fla., though temperatures at Beaufort were somewhat lower than those at Key West.

4. A method of and device for determining the flexibility of lines and changes therein brought about by the application of preservatives were devised, tested, and used. A description and discussion of this method and device are given (p. 20).

5. In diminishing the flexibility of the cotton lines the tars, petroleum residues, and gilsonite had the greatest effect, the copper paints had a large effect, the tanning methods caused some stiffening, and copper oleate had less effect than any other preservative studied.

6. A machine for determining the ability of lines to endure mechanical wear or abrasion was devised, tested, and used. A description and discussion of this device are given (p. 25).

7. In wearing ability the copper paints, which made such a good showing in preserving tensile strength, were at a great disadvantage. The lines treated with these and those treated with quercitron and potassium bichromate wore very poorly; those treated by the Dutch method wore rather better than those treated with copper paints or by quercitron and potassium bichromate; those treated with tar resisted mechanical abrasion well at first, but this quality was lost on exposure along with the disappearing tensile strength. The copper oleates, when applied as preservatives, enabled the lines to resist mechanical abrasion better than any of the preservatives.

8. All lines, except those treated with copper paint or copper oleate, were fouled by marine growths in four months at Beaufort. The lines treated by the Dutch method, which also contained copper, were slightly fouled. The lines treated by quercitron and potassium bichromate and those treated with a petroleum product were very heavily fouled. Copper oleate and copper paint effectually prevent fouling.

9. Of the linen lines only those treated with copper oleate or by the Dutch method endured four months' exposure at Beaufort. Of these two copper oleate was more efficacious and much easier to apply.

10. Linen lines deteriorated in sea water at Beaufort more rapidly than cotton lines, whether preserved or not.

SERIES EXPOSED IN SEA WATER AT WOODS HOLE, MASS.

Beginning June 9 and extending to December 9, 1922, a period of six months, a series of lines preserved with various materials was exposed in sea water at Woods Hole, Mass.

WATER CONDITIONS AT WOODS HOLE.

The water conditions at Woods Hole were different from those at either Key West or Beaufort, being cooler. The temperature and specific gravities that prevailed at Woods Hole during the period of test are shown in Table 11. The samples were suspended under the dock at the station of the U. S. Bureau of Fisheries Biological Laboratory. The water is full sea water, and the samples were subjected to the regular ebb and flow of the tide.

TABLE 11.—*Water conditions at Woods Hole, Mass.*

Year and month.	Temperature.						Specific gravity.		
	Maximum.		Minimum.		Average.		Maximum.	Minimum.	Average.
1922.	°F.	°C.	°F.	°C.	°F.	°C.			
June	66	18.3	61	16.1	63	17.2	1.024	1.023	1.023
July	69	20.5	65	18.3	67	19.4	1.024	1.023	1.023
August	71	21.6	66	18.8	68	20.0	1.024	1.023	1.023
September	68	20.0	62	16.6	66	18.8	1.023	1.022	1.022
October	64	17.7	50	10.0	59	15.0	1.025	1.023	1.023
November	51	10.5	40	4.4	47	8.3	1.025	1.024	1.024
December	42	6.0	31	−0.56	37	2.7	1.025	1.025	1.025

TESTS WITH COTTON LINES.

MATERIALS TESTED.

The lines tested in this series were the same as in the preceding experiments, No. 24 cable-laid hard-finish cotton twine.

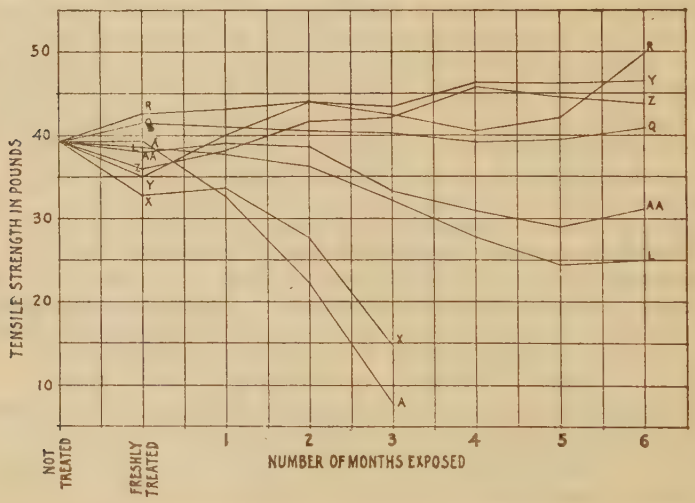

FIG. 21.—Tensile strength of cotton lines exposed in sea water at Woods Hole, Mass.

The preservatives and preservative methods tested were the Dutch method, L; copper paints Nos. 1 and 2, Q and R; petroleum product No. 2, X; copper oleate followed by coal tar diluted with benzol, Y; and copper oleate mixed with coal tar and the whole diluted with benzol, Z; copper oleate in 15 per cent solution in gasoline, AA; and the untreated line A, as control. The lines were measured and weighed, as before described (p. 9), treated, and again measured and weighed. The shrinkage and increase in weight will be considered later.

TENSILE STRENGTH.

Table 12 gives the results of tensile strength measurements on the unexposed and exposed cotton lines of the Woods Hole series. These results are shown graphically in Figure 21

TABLE 12.—*Tensile strength of cotton lines exposed in sea water at Woods Hole, Mass.*

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Tensile strength in pounds.						
A—Untreated white line	[1] 39.3	39.0	20.1	8.0	[2]	[2]	[2]
L—Dutch method	38.6	38.0	37.0	34.0	26.1	23.0	24.7
Q—Copper paint No. 1	41.5	42.0	40.0	40.0	40.6	37.0	40.8
R—Copper paint No. 2	42.7	42.0	45.0	45.0	37.5	39.0	49.6
X—Petroleum product No. 2	32.9	45.0	23.0	15.0	[2]	[2]	[2]
Y—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent	35.0	43.0	42.0	47.0	42.6	50.0	46.5
Z—Copper oleate followed by coal tar	36.0	38.0	39.0	48.0	40.0	50.0	43.6
AA—Copper oleate, alone, 15 per cent gasoline	38.0	42.0	37.0	37.0	26.0	30.0	31.0

[1] Average of 60 breaks; every other figure in this table is the average of 15 breaks.
[2] Line was disintegrated and gone.

The lines treated with petroleum product No. 2, designated X, is scarcely better than the untreated line, A. This result is in keeping with the result obtained with the same preservative at Beaufort. The copper oleate, AA, employed in this case, is strikingly similar to the Dutch method, L, both of which show good preservation, though, as before, these preservatives do not add anything to the strength of the lines by a sticky effect on the fibers. When allowance is made for this effect in the lines treated with copper paint or the combinations of copper oleate and tar (Q, R, Y, and Z), strikingly similar preservation effect is noticed. As might be expected, the lines treated with copper oleate and tar behave very much like those treated with copper paint, since the mixture of copper oleate and tar is very similar to copper paint in composition. Each consists of a form of copper incorporated in a binder—the paints containing copper oxide, the tar mixture containing copper oleate. It should be noticed here, however, that the tar mixtures contain very much less copper than the copper paints and should accordingly be cheaper, though they preserve fully as well.

Between the two combinations of tar and copper oleate—that is, the separate application of the copper oleate and tar in the one case and the mixture of the two for application in the other—there is little difference. The combination can be easily and simply applied, since both the copper oleate and tar are soluble in benzol and may be applied cold. Perhaps the separate application of tar and copper oleate is slightly better, though the extra time and labor required to make the two applications would probably more than make up the difference. On the other hand, the separate application may be employed without the use of benzol by using a gasoline solution of copper oleate and following with tar in the usual way by the hot process.

These combinations of copper oleate and tar furnish a new possibility where nets are exposed to the most extreme conditions for long periods. Straight copper oleate is toxic and preserves to a high degree, but contains nothing in the way of a binder to hold it in the lines. When combined with tar it constitutes a permanent toxic ingredient that will stay in the lines over long periods, although

creosote, the natural toxic principle of fresh tar, escapes during a short term of exposure.

It may further be noticed that the water at Woods Hole is not so severe in its effect on lines as that at Beaufort. The strength of the lines after the second month at Beaufort is similar to that of the Woods Hole lines after the fourth month.

FLEXIBILITY.

The samples used in this test were tested for flexibility by the pendulum method already described. The results of these tests are given in Table 13 and are shown graphically in Figure 22.

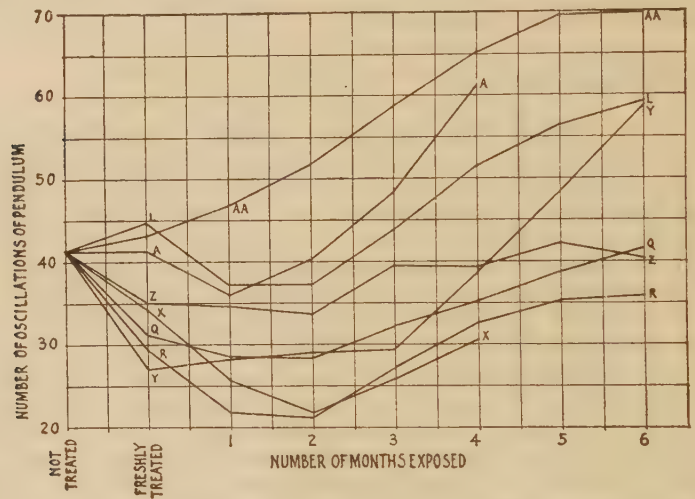

FIG. 22.—Flexibility of cotton lines exposed in sea water at Woods Hole, Mass.

TABLE 13.—*Flexibility of cotton lines exposed at Woods Hole, Mass.*[1]

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Number of oscillations.						
A—Untreated white line control	41.3	36.8	32.2	51.3	61.2	(2)	(2)
L—Dutch method	44.9	33.8	33.6	44.4	53.6	56.6	59.3
Q—Copper paint No. 1	31.1	26.5	28.1	30.8	37.4	37.2	41.5
R—Copper paint No. 2	29.4	16.5	19.5	27.5	34.4	35.6	35.6
X—Petroleum product No. 2	34.3	18.4	24.7	22.4	30.5	(2)	(2)
Y—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent	27.0	30.5	27.7	28.8	31.7	55.3	58.6
Z—Copper oleate followed by coal tar	35.3	30.0	39.0	31.9	47.8	38.4	40.3
AA—Copper oleate 15 per cent in gasoline	43.1	46.4	51.0	56.9	68.9	70.5	70.0

[1] Each figure in this table is the average of 100 tests.
[2] Line was disintegrated and gone.

The general trend of the lines is at first toward a slight stiffening and later toward an increasing flexibility. The line AA, preserved with copper oleate, easily leads all the lines in flexibility, being more

flexible than the untreated lines. The lines treated by the Dutch method were also sufficiently flexible. The copper paints, Q and R, tar and copper combinations, Y and Z, and petroleum product No. 2, designated by X, cause marked stiffening, all to about the same extent. Though the lines treated with petroleum product are, by a little, the stiffest, the copper paints also cause marked stiffening, and, upon comparison with the tar-copper-oleate combinations, show slight advantage in favor of the latter. Here, again, the copper

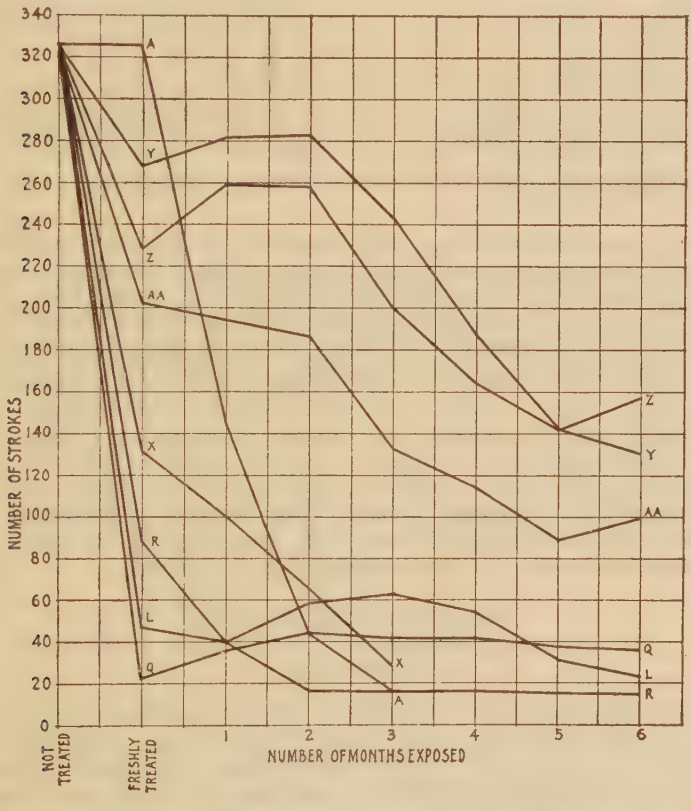

FIG. 23.—Wearing quality of cotton lines exposed in sea water at Woods Hole, Mass.

paints and tar-copper-oleate combinations, being somewhat similar in composition, give similar results. None of these materials would be suitable where flexibility is desired, but they are otherwise excellent preservatives.

WEARING QUALITY.

By the method already described, of sawing the lines against themselves (p. 25), the ability of the various lines exposed at Woods Hole to resist mechanical wear, was measured. The results are given in Table 14 and are shown graphically in Figure 23.

TABLE 14.—*Wearing quality of cotton lines exposed to sea water, Woods Hole, Mass.*

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Number of strokes.						
A—Not treated	[1] 399.0	80.9	37.0	17.5	[2]	[2]	[2]
L—Dutch method	46.6	29.8	53.7	95.4	40.4	30.5	23.9
Q—Copper paint No. 1	23.0	51.3	36.4	47.4	43.9	36.1	35.6
R—Copper paint No. 2	89.0	15.6	17.4	19.4	15.6	14.6	14.8
X—Petroleum product No. 2	132.0	104.0	67.1	29.6	[2]	[2]	[2]
Y—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent	268.3	297.6	282.6	269.4	180.4	115.3	130.3
Z—Copper oleate followed by coal tar	228.1	299.0	250.3	227.6	127.3	138.7	157.0
AA—Copper oleate, 15 per cent in gasoline	203.1	228.0	155.6	178.7	66.1	101.7	99.8

[1] Average of 100 tests; every other figure in this table is the average of 50 tests.
[2] Line was disintegrated and gone.

It has been noticed that, with respect to tensile strength and flexibility, the copper paints and the tar-copper-oleate mixtures run "neck and neck." They differ widely, however, when their wearing quality is measured. The tar-copper-oleate mixtures, Y and Z, lead the entire series in this respect, while the copper paints, Q and R, take last place, as they did in the other series. This might be expected, since copper paint makes the lines harsh, and copper oleate, on the other hand, is smooth or waxy in consistency. Next to the tar and copper mixture is copper oleate alone, AA, then the Dutch method, L, which comes low in the series, because it, too, makes the lines to which it is applied harsh. The petroleum product No. 2, designated X, is here again very low, running only a little better than the white line, A, upon exposure in sea water.

TESTS WITH LINEN LINES.

MATERIALS TESTED.

Besides the tests with cotton lines at Woods Hole, just described, there were also conducted some tests of linen lines. As before, 10-ply linen, such as is used in salmon gill netting, was used. The lines were prepared and placed in the water along with the cotton lines on June 9, 1922, and samples were removed after the first, second, and third months, the test running in this case only three months. Linen lines are in practice of course never exposed continuously in the water. For purposes of experiment, however, it seemed that the effects of the preservatives could be brought out more certainly in this way, without the possible entrance of other complicating factors, if intermittent exposure had been attempted. Since linen lines do not wear at all well on the wearing-test machine and the preservatives applied to it increase stiffness very little, tests of these two factors were omitted, and only the tensile strength, shrinkage, and increase in weight were determined.

The preservatives and preservative methods tested were Dutch method, W; petroleum product No. 2, BB; and copper oleate, CC. Untreated linen line, T, was used as control.

TENSILE STRENGTH.

The results of determination of tensile strength before and after exposure are shown in Table 15 and in Figure 24.

TABLE 15.—*Tensile strength of linen lines exposed in sea water at Woods Hole, Mass.*

Symbol and treatment.	Unexposed.	Number of months exposed.		
		1	2	3
	Tensile strength in pounds.			
T—Not treated	[1] 55.2	48	27	27
W—Dutch method	43.0	56	20	34
BB—Petroleum product No. 2	49.0	44	12	8
CC—Copper oleate, 15 per cent in gasoline	48.0	48	43	51

[1] Average of 50 breaks; every other figure in this table is the average of 15 breaks.

Although the Dutch method here shows some merit, copper oleate easily leads, linen lines treated with it finishing the three months in the water with the original strength unimpaired. The petroleum product here, as elsewhere, failed to effect any noticeable preservation of the lines treated with it.

SUMMARY OF RESULTS OF WOODS HOLE EXPERIMENTS.

1. For cotton line seven preservatives and preservative methods and untreated line as control were tested at Woods Hole, Mass., being exposed from June 9 to December 9, 1922. The preservatives and preservative methods were two copper paints, two combinations of copper oleate and tar, the Dutch method, copper oleate, and petroleum product No. 2.

2. For linen lines three preservatives and preservative methods and the untreated line as control were tested, being exposed from June 9 to September 9, 1922. The preservatives and preservative methods were Dutch method, petroleum product No. 2, and copper oleate.

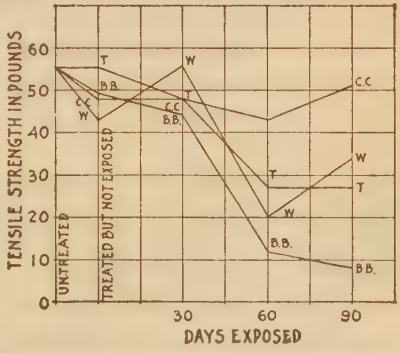

FIG. 24.—Tensile strength of linen lines exposed in sea water at Woods Hole, Mass.

3. Exposure in the water at Woods Hole had a much less severe effect on lines, treated or not, than at Beaufort.

4. In combinations of copper oleate and tar it made little difference whether the two were mixed and applied or applied separately.

5. These combinations of copper and tar effected about the same degree of preservation of tensile strength and stiffened the lines to about the same degree as the copper paints but were far superior to copper paints in mechanical wearing quality.

6. Copper oleate alone here, as elsewhere, produced a very flexible line; it held tensile strength during exposure about like the Dutch method for cotton lines. Copper oleate excelled in wearing quality but did not equal in this respect the combinations of copper oleate and tar.

7. The petroleum product No. 2 proved to be a poor preservative in all respects studied.

8. The Dutch method, in preservation of tensile strength and in flexibility, was intermediate in value between the best and poorest; in mechanical wearing quality it was inferior.

9. The copper paints preserved tensile strength well, greatly stiffened the lines, and wore poorly.

SERIES EXPOSED IN FRESH WATER AT PUT IN BAY, OHIO.

All the exposures of lines in water so far described were in sea water at Key West, Beaufort, and Woods Hole. It is important to determine how preservatives behave in fresh water also. Since Lake Erie is the seat of one of our greatest fresh-water fisheries, where the art of constructing and using fishing nets has been brought to a high degree of perfection, it seemed appropriate to make a series of experimental exposures in its waters. Accordingly, a series identical with the Woods Hole series in the lines and preservatives used was prepared and placed in the water at the U. S. Bureau of Fisheries hatchery at Put in Bay, Ohio, June 15, 1922. The series for cotton lines was exposed till December 15, 1922.

WATER CONDITIONS AT PUT IN BAY.

The temperatures of the water at Put in Bay are shown in Table 16.

TABLE 16.—*Temperature of water at Put in Bay, Ohio.*

Year and month.	Maximum.		Minimum.		Average.	
1922.	°F.	°C.	°F.	°C.	°F.	°C.
June	73	22.7	65	18.3	70	21.1
July	77	25.0	72	22.2	75	23.8
August	77	25.0	72	22.2	75	23.8
September	76	24.4	66	18.8	71	21.6
October	68	20.0	50	10.0	59	15.0
November	53	11.6	38	3.3	47	8.3
December	39	3.8	33	.5	35	1.6

It is well known that fresh water in Lake Erie is very severe in its effect on lines. A red slime becomes deposited on the nets in the summer season, and a strong deterioration of nets occurs at the same time. This red slime consists of hydroids, colonies of small animals that may or may not directly affect the nets. At any rate, decomposition of the samples was rapid, as will be seen, and the order of effectiveness of the different preservatives differed considerably from that of the salt-water experiments.

TESTS WITH COTTON LINES.

MATERIALS TESTED.

The preservatives and preservative methods tested for cotton lines were the Dutch method, L; copper paints, Nos. 1 and 2, Q and R; petroleum product No. 2, designated X; copper oleate in gasoline, AA; copper oleate followed by coal tar diluted with benzol, Y; and copper oleate mixed with coal tar and the whole diluted with benzol, Z. The shrinkage and increase in weight caused by the preservatives were noted; the data for these factors will be considered later.

TENSILE STRENGTH.

The tensile strength of the lines exposed at Put in Bay are given in Table 17 and are shown graphically in Figure 25.

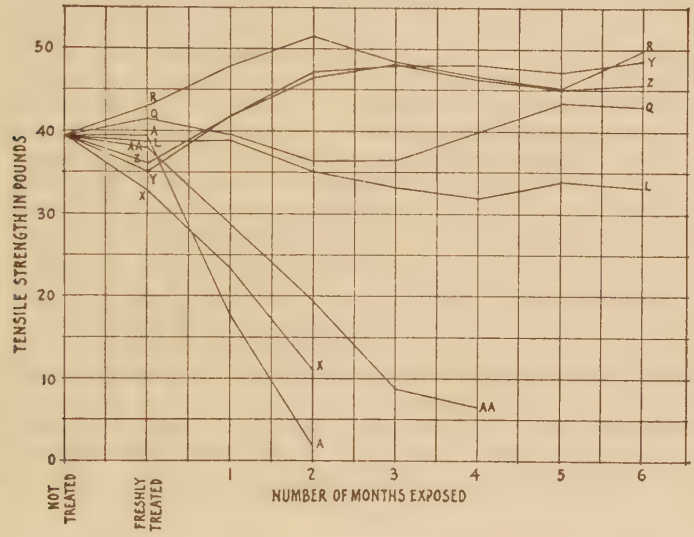

FIG. 25.—Tensile strength of cotton lines exposed in fresh water at Put in Bay, Ohio.

TABLE 17.—*Tensile strength of cotton lines exposed in fresh water at Put in Bay, Ohio.*

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Tensile strength in pounds.						
A—White line, untreated control	[1] 39.3	12.3	1.7	[2]	[2]	[2]	[2]
L—Dutch method	38.6	40.0	38.0	27.0	34.1	34.0	33.0
Q—Copper paint No. 1	41.5	39.0	38.0	32.0	39.6	48.0	42.7
R—Copper paint No. 2	42.7	52.0	49.0	53.0	42.3	44.0	49.7
X—Petroleum product No. 2	32.9	26.0	11.0	[2]	[2]	[2]	[2]
Y—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent	35.0	46.0	44.0	51.0	47.8	45.0	48.4
Z—Copper oleate followed by coal tar	36.0	42.0	47.0	50.0	46.6	42.0	45.6
AA—Copper oleate 15 per cent in gasoline	38.0	38.0	10.0	10.0	6.5	[2]	[2]

[1] Average of 60 breaks; every other figure in this table is the average of 15 breaks.
[2] Line was disintegrated and gone.

Here, as at Woods Hole, the copper paints, Q and R, run very close to the copper oleate and tar combinations. The copper paint No. 2, (R), containing, as it does, much more copper than No. 1, (Q), stands first; then come the copper and tar combinations, followed by copper paint No. 1. Both the copper paints, however, contain much more copper than either of the copper and tar mixtures. A striking difference from the Woods Hole series (and the other salt-water experiments) is found in the behavior of copper oleate alone and the Dutch method. In all the salt-water tests, without exception, copper oleate preserved better than the Dutch method. Here, however, the Dutch method stands higher, comparing favorably with the copper paints and the copper and tar mixtures, while copper oleate, doing well the first 30 days, afterwards fails rapidly.

It seems likely that the cause of this peculiar difference lies in the comparative solubilities of the copper compounds present. The Dutch method deposits copper tannate, which appears to remain in the lines; but the copper oleate was not very plainly visible in the lines returning from these fresh-water experiments as it was in the salt-water series. It may be that the copper oleate is too soluble in fresh water and gradually dissolves out, while the tannate is less soluble. If this is so, why the reverse condition of results from salt water? Copper oleate appears to be less soluble in salt water than in fresh. A certain degree of solubility of the active ingredient may be necessary, for a totally insoluble material may be inert and ineffectual as a preservative. Sea water, being an electrolyte, precipitates many colloids—as it will precipitate soap. Copper oleate is a soap and is probably soluble to a small degree as such in fresh water, although not soluble to the same extent in salt water.

That a binder may hold the copper oleate in the lines and in that way prolong its preservative effect is shown by the copper oleate and tar combinations. The remedy indicated for the shortcoming of copper oleate in fresh water may be found in the use of a binder that will keep the copper oleate present and not greatly increase stiffness and weight. Experiments in this field are planned for the near future.

FLEXIBILITY.

The flexibility of the cotton lines exposed at Put in Bay was tested in the way previously described (p. 20), both before and after exposure. The results are given in Table 18 and are shown graphically in Figure 26.

TABLE 18.—*Flexibility of cotton lines exposed in fresh water at Put in Bay, Ohio.*[1]

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Number of oscillations.						
A—White line, untreated control	41.3	62.7	69.1	(2)	(2)	(2)	(2)
L—Dutch method	44.9	52.5	51.4	53.3	58.7	67.1	59.2
Q—Copper paint No. 1	31.1	34.1	38.7	39.5	44.2	45.0	46.8
R—Copper paint No. 2	29.4	16.3	22.1	21.3	30.1	37.4	37.3
X—Petroleum product No. 2	34.3	24.2	37.3	(2)	(2)	(2)	(2)
Y—Copper oleate, 15 per cent; benzol, 35 per cent; coal tar, 50 per cent	27.0	30.0	31.1	28.4	34.2	52.4	54.2
Z—Copper oleate followed by coal tar	35.3	30.5	34.1	49.7	49.2	40.5	58.0
AA—Copper oleate, 15 per cent, in benzol	43.1	69.7	74.0	73.5	78.3	(2)	(2)

[1] Every figure in this table is the average of 100 tests. [2] Line was disintegrated and gone.

The most flexible of all the lines exposed are those treated with copper oleate, AA; then comes untreated line, A, and that treated by the Dutch method, L. Considered together the lines treated with copper oleate and tar combinations, Y and Z, and copper paints, Q and R, are very stiff, though the stiffest is copper paint No. 2, R, and the most flexible is the combination, Z, which is copper oleate followed by tar, with copper paint No. 1, Q, and the mixed copper oleate and tar, Z, an intermediate. The petroleum residue, X, also markedly stiffens the lines.

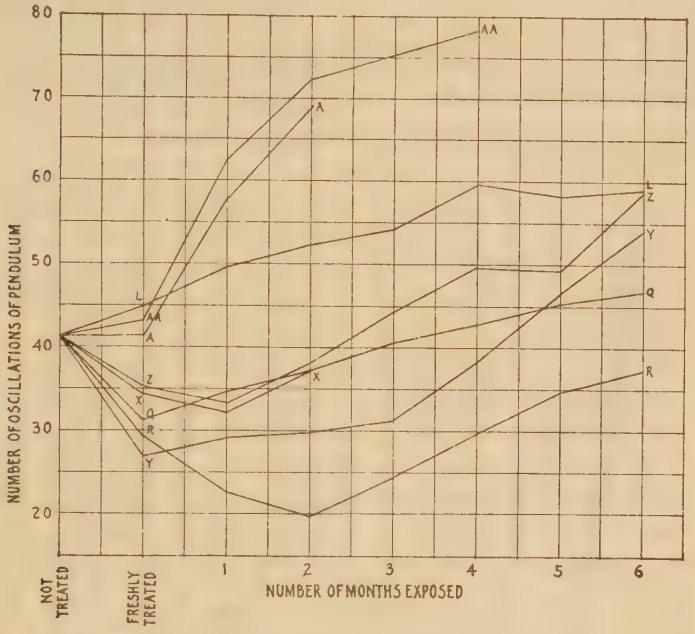

FIG. 26.—Flexibility of cotton lines exposed in fresh water at Put in Bay, Ohio.

The tendency toward increasing flexibility of all the lines is an indication of general deterioration; as they lose in strength and general quality they become more and more flexible.

WEARING QUALITY.

The results of the tests of wearing quality of the lines in the Put in Bay series are given in Table 19 and are shown graphically in Figure 27.

TABLE 19.—*Wearing quality of lines exposed in fresh water at Put in Bay, Ohio.*

Symbol and treatment.	Unexposed.	Number of months exposed.					
		1	2	3	4	5	6
	Number of strokes.						
A—White line, untreated control	[1]399.0	2.1	(2)	(2)	(2)	(2)	(2)
L—Dutch method	46.6	44.8	43.6	46.6	42.7	24.8	35.5
Q—Copper paint No. 1	23.0	41.7	28.9	29.8	34.8	31.1	31.5
R—Copper paint No. 2	89.0	25.6	29.2	24.8	19.2	16.3	15.3
X—Petroleum product No. 2	132.0	37.6	4.8	(2)	(2)	(2)	(2)
Y—Copper oleate, 15 per cent; benzol, 35 per cent; coal tar, 50 per cent	268.3	227.4	222.9	189.3	150.6	88.1	92.0
Z—Copper oleate followed by coal tar	228.1	231.2	274.9	130.0	153.4	121.8	111.5
AA—Copper oleate, 15 per cent in gasoline	203.1	180.8	18.1	8.6	4.2	(2)	(2)

[1] Average of 100 tests; every other figure in this table is the average of 50 tests.
[2] Line was disintegrated and gone.

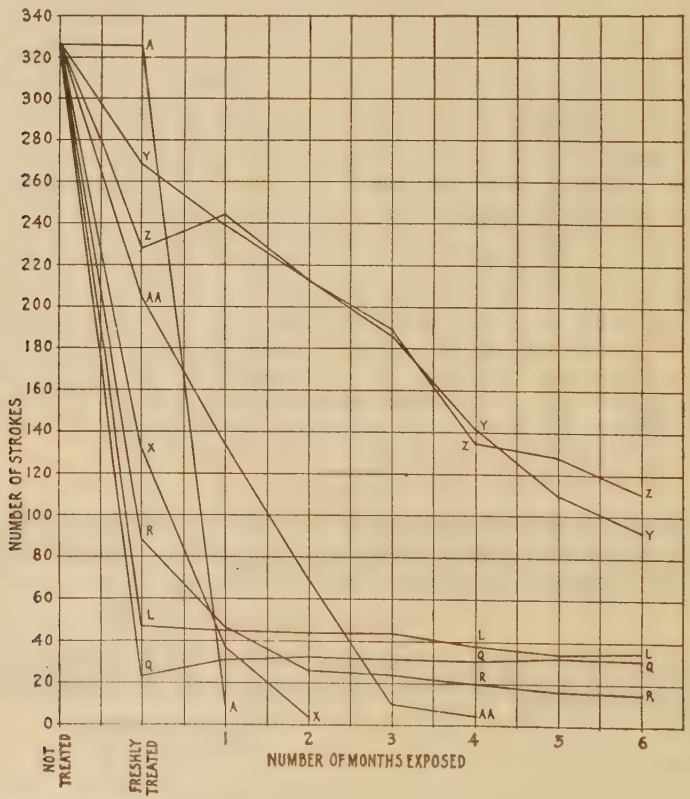

FIG. 27.—Wearing quality of cotton lines exposed in fresh water at Put in Bay, Ohio.

The leaders in this test are by long odds the lines preserved with the copper oleate and tar combinations which, even after three months' exposure, are still more resistant to wear than any of the others even before exposure, with the single exception of unexposed white line. This result agrees with the result at Woods Hole, where

the copper oleate and tar combinations showed exceptional wearing quality. Running, as they do, very close to the copper paints in flexibility and tensile strength, they excel copper paints so much in wearing quality that their selection is already indicated for the heavier types of gear where wear is a consideration. Copper oleate alone, AA, since it failed to preserve tensile strength, of course failed also in wearing quality, because, as already pointed out, if tensile strength is impaired the lines will make a poor showing in wearing quality whatever the results might otherwise be. We already know from the other series that copper oleate is better in wearing quality than any other preservative studied, and we can therefore with assurance ascribe its failure here to failure to preserve the strength of the fibers.

The Dutch method, L, does not show a wearing quality that can be called satisfactory, It makes only 43 to 46 strokes on the wearing machine against 399 for fresh white line and 231 for lines freshly treated with copper oleate and tar. Nevertheless, the uniformity of results indicates good preservation, as was seen in its effect on tensile strength. The Dutch method is therefore in fresh water a good preservative in general for cotton lines, though it leaves much to be desired in the particular factor of wearing quality. The petroleum product No. 2, designated X, is no better in wearing quality than in other particulars—it fails consistently, as far as tested, and excels in no quality.

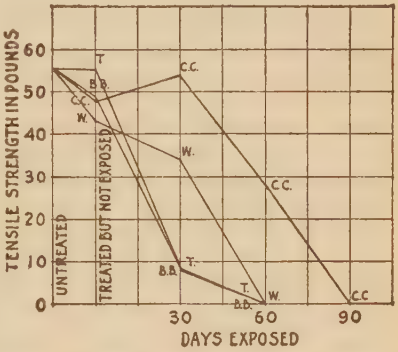

FIG. 28.—Tensile strength of linen lines exposed in fresh water at Put in Bay, Ohio.

TESTS WITH LINEN LINES.

MATERIALS TESTED.

A series of linen lines identical in material, preservatives, and preservative methods used with those at Woods Hole was exposed at Put in Bay for a three months' period. The line was 10-ply linen gill netting. The preservatives and preservative methods used were copper oleate, 12½ per cent concentration in gasoline and 5 per cent oil, CC; the Dutch method, W; petroleum product No. 2, designated BB.

TENSILE STRENGTH.

The tensile strength of these lines before and after exposure is given in Table 20, the same results appearing graphically in Figure 28.

TABLE 20.—*Tensile strength of linen lines exposed in fresh water at Put in Bay, Ohio.*

Symbol and treatment.	Unexposed.	Number of months exposed.		
		1	2	3
	Tensile strength in pounds.			
T—Untreated line, control	[1] 55.2	7.7	[2]	[2]
W—Dutch method	43.0	34.0	[2]	[2]
BB—Petroleum product No. 2	49.0	8.2	[2]	[2]
CC—Copper oleate, 15 per cent in gasoline	48.0	54.0	28.0	[2]

[1] Average of 50 tests; every other figure in this table is each the average of 15 tests.
[2] Line was disintegrated and gone.

In this series the only preservative that shows any considerable success is copper oleate, CC; all three of the other lines—that is, the untreated line controls, T, and the samples treated by the Dutch method, W, and with the petroleum product No. 2, designated BB—failed to appear at all after one month of exposure. Of course, linen gill netting in practice would not be exposed to such conditions; but all the lines received similar exposure, and copper oleate clearly preserved better than any of the others.

Just why copper oleate preserved better with linen line than with cotton relatively to the other preservatives is not apparent. The conditions at Put in Bay are worse for the lines, both cotton and linen, than they are at either Woods Hole or Beaufort. At Beaufort two of the linen samples—that is, the ones treated with copper oleate and by the Dutch method—came through 120 days with some strength left, and at Woods Hole the corresponding samples were in good shape after 90 days, those preserved with copper oleate still being equal in tensile strength to the original lines. Linen is like cotton in showing more rapid deterioration in Lake Erie than the Atlantic Ocean; but copper oleate preserved linen relatively better than it did cotton.

SUMMARY OF RESULTS OF PUT IN BAY EXPERIMENTS.

1. The samples exposed at Put in Bay, Ohio, showed a general tendency toward a more rapid deterioration than did similar lines exposed in sea water.

2. The exceptions to this statement were those lines treated with the copper paints and tar-copper-oleate combinations, which showed no deterioration of tensile strength in fresh or salt water in six months, and the Dutch method, which preserved cotton lines better in fresh water than it did in salt water.

3. For cotton lines the copper paints and the combination of copper oleate and tar gave splendid results, but both classes of the preservatives stiffened the lines greatly.

4. As between copper paints and the tar-copper-oleate combinations, the preservation of tensile strength was equal, although in wearing quality the tar-copper-oleate combinations greatly excelled.

5. The Dutch method gave excellent results on cotton lines in this series, preserving the samples for the entire six months' period and not causing excessive stiffness.

6. Copper oleate alone did not excel in the preservation of cotton lines in this fresh-water series, apparently because it dissolves in fresh water and is removed from the lines.

7. On linen lines copper oleate preserved better in this series than did the Dutch method—the reverse of the results on cotton lines.

OTHER CONSIDERATIONS OF IMPORTANCE IN JUDGING VALUE OF PRESERVATIVES.

VARYING RATE OF DECOMPOSITION OF LINES IN DIFFERENT LOCALITIES.

It is generally understood that lines decompose more rapidly in some localities than in others and more rapidly in summer than in winter, but no quantitative data on the subject have been published. For purposes of comparison the tensile strength records of the untreated cotton lines exposed in the several series are given in Figure 29. It will be noted that the line lasted over the entire six months'

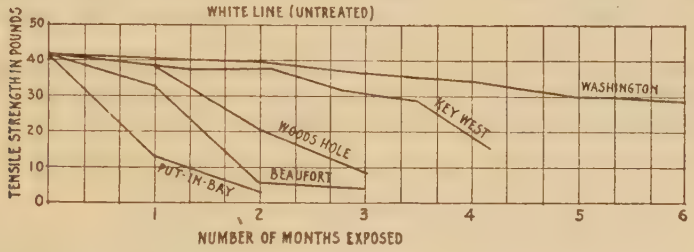

FIG. 29.—Varying rate of decomposition of cotton lines in different localities.

period of exposure to weather conditions at Washington, D. C., and over the entire period of 4½ months at Key West, Fla. At both Woods Hole, Mass., and Beaufort, N. C., the lines were entirely disintegrated and gone at the end of 4 months, though at the end of 4 months the line from Woods Hole showed a tensile strength of about 10 pounds and the one from Beaufort of about 3 pounds. In fresh water at Put in Bay the line showed a tensile strength of but about 2 pounds at the end of 2 months and at the end of 3 months was entirely rotten. The average specific gravity of the water at Key West for the entire period of exposure was 1.025, at Woods Hole 1.023, at Beaufort 1.019, and at Put in Bay about 1.000. Thus, considered roughly, the rate of deterioration of the exposed lines is directly proportional to the specific gravity (salinity) of the water in which they were exposed.

There is in all probability a relation also between the temperature of the water and the rate at which a line exposed in it will deteriorate; other factors being held constant the rate of deterioration of a line would no doubt bear an inverse relation to the temperature. The temperature records given for the localities of exposure do not show this relation here. Salinity differences complicate the results, and also, because the exposures were made in different seasons at the different places, the fluctuations in temperatures are very unlike.

INCREASE IN WEIGHT CAUSED BY APPLICATION OF PRESERVATIVES.

Among the properties of textiles that make them suitable for fishing is lightness. A light net is more easily and more rapidly handled than a heavy one, and consequently less labor is required to handle it. Since a net must support its own weight, the weight added to a net in the substance of a preservative adds just so much to the load to be carried by the net.

It is therefore important to determine the increase in weight caused by preservation and to select the preservatives that impart least weight to the nets, other conditions being the same. In all the series of experiments so far described in this paper this factor was determined by weighing the sample lines before and after treatment. These weighings were made on the analytical laboratory balance, but the lines were not dried to constant weight. It was found by experiment that, unless elaborate precautions were taken, the perfectly dried sample reabsorbed moisture so rapidly from the air that accurate weighing was impossible. Since it was impractical to use weighing bottles to prevent this and would be improper to heat the treated nets to the temperature required for drying, the samples were weighed in the air-dry condition.

Table 21 gives the results of the determinations of increase in weight of cotton and linen lines caused by the preservatives. These results are shown graphically in Figures 30 and 31.

TABLE 21.—*Increase in weight of cotton and linen lines caused by application of preservatives.*

COTTON LINES.

Symbol and treatment.	Per cent increase in weight.					
	Washington.	Key West.	Beaufort.	Woods Hole.	Put in Bay.	Average.
B—Copper oleate 7 per cent	11	16	.....	.....	.....	13
C—Copper oleate 7 per cent, 5 per cent paraffin oil, 1–1000 cresol	15	26	.....	.....	.....	20
D—Copper oleate 11 per cent	16	37	.....	.....	.....	26
E—Copper oleate 11 per cent, 2 per cent paraffin oil	21	31	.....	.....	.....	26
F—Coal tar 50 per cent, benzol 50 per cent	71	69	66	.....	.....	69
G—Pine tar 50 per cent, benzol 50 per cent	50	49	57	.....	.....	52
H—Coal tar and pine tar each 25 per cent, benzol 50 per cent	58	47	41	.....	.....	48
I—Quercitron and potassium bichromate	7	6	13	.....	.....	8
J—Petroleum product No. 1	51	52	41	.....	.....	48
K—Proprietary waterproofing material	17	17	.....	.....	.....	17
L—Dutch method	21	9	13	23	19	17
M—Copper oleate 7½ per cent	.....	.....	9	.....	.....	9
N—Copper oleate 12½ per cent, 5 per cent paraffin oil, 1–1000 cresol	.....	.....	14	.....	.....	14
O—Copper oleate 12½ per cent	.....	.....	15	.....	.....	15
P—Copper oleate 12½ per cent, 5 per cent paraffin oil	.....	.....	19	.....	.....	19
Q—Copper paint No. 1	.....	.....	48	74	75	66
R—Copper paint No. 2	.....	.....	109	138	132	126
S—Gilsonite	.....	.....	46	.....	.....	46
X—Petroleum product No. 2	.....	.....	37	36	35	36
Y—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent	.....	.....	.....	58	56	57
Z—Copper oleate 15 per cent, followed by coal tar	.....	.....	.....	59	62	60
AA—Copper oleate 15 per cent	.....	.....	.....	18	18	18

LINEN LINES.

Symbol and treatment.	Beaufort.	Woods Hole.	Put in Bay.	Average.
U—Copper oleate 12½ per cent in gasoline, 5 per cent paraffin oil	30.8	.....	.....	30.8
V—Quercitron and potassium bichromate	15.6	.....	.....	15.6
W—Dutch method	26.2	31.2	29.8	29.0
BB—Petroleum product No. 2	.....	35.7	39.4	37.5
CC—Copper oleate 15 per cent in gasoline	.....	22.0	23.3	22.6

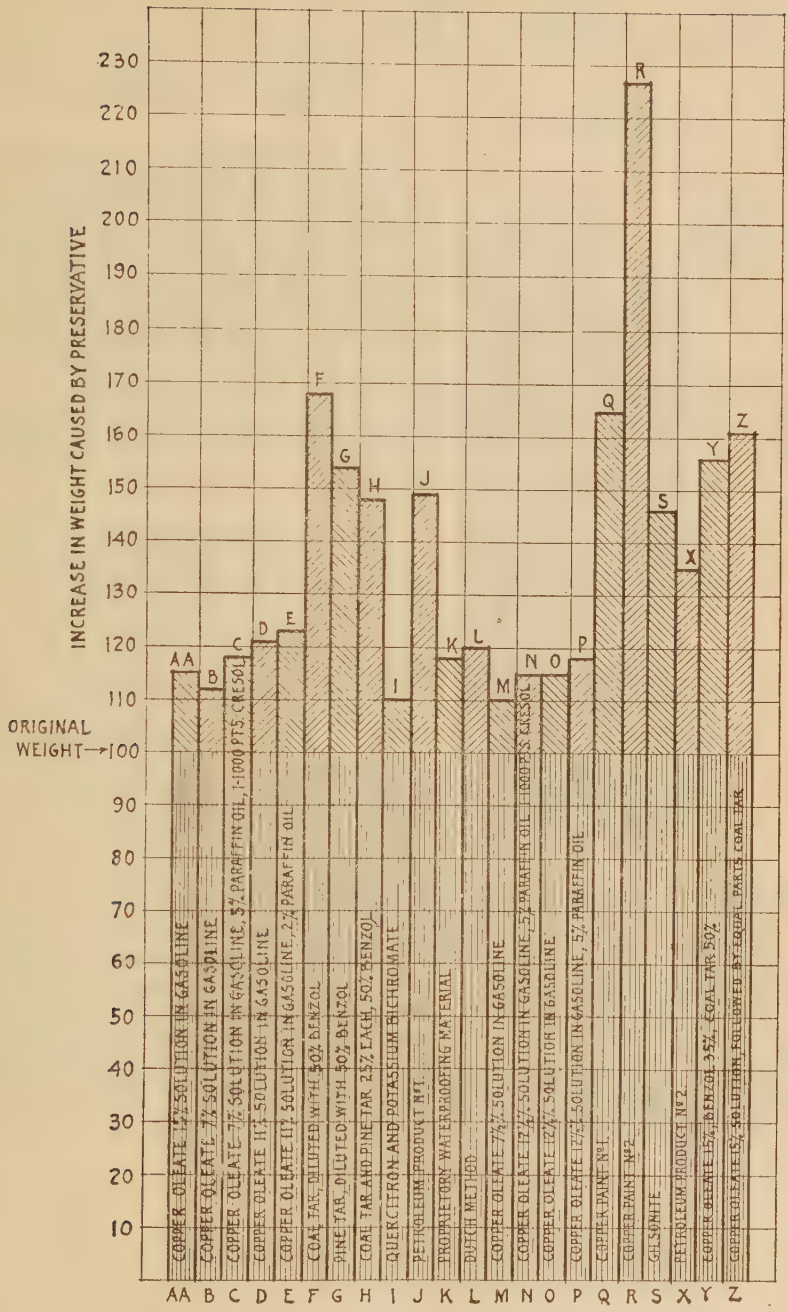

FIG. 30.—Increase in weight of cotton lines caused by one application of the various preservatives.

In Figures 30 and 31 the original weight of the line is represented by the height of the polygon up to 100. The diagonally hatched part above 100 represents the weight added by the preservative, and the total height of the polygon represents the total weight of the line after treatment.

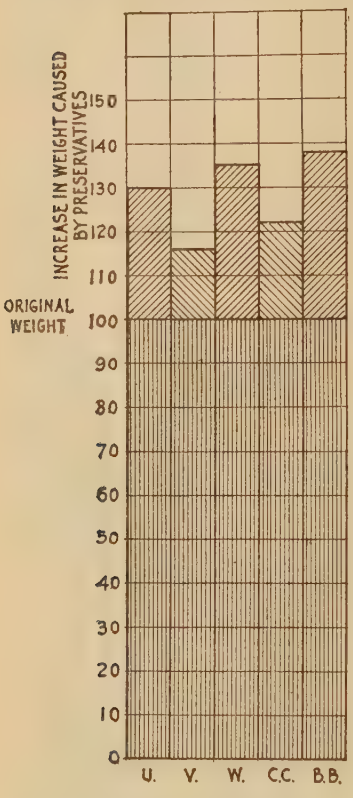

FIG. 31.—Increase in weight of linen lines caused by one application of various preservatives. U, copper oleate, 12½ per cent solution in gasoline, 5 per cent paraffin oil; W, Dutch method; V, quercitron and potassium bichromate; BB, petroleum product No. 2; CC, copper oleate, 15 per cent solution in gasoline.

It is readily seen that certain materials, such as tar and copper paint, very greatly increase the weight of the lines, while others, notably the tanning methods and copper oleate, add very little to the weight. Tar, which shows a considerable increase, would probably show even a greater increase in weight where it is applied by the hot method. Copper paint, which made such a good showing in preservation of tensile strength, here makes a very poor showing in that it causes a great increase in weight.

It was noticed in connection with the data on tensile strength that certain preservatives actually increased tensile strength by their binding effect on the fibers. The preservatives that have the greatest effect in this way are also those that increase weight most. The question then arises, Does the extra tensile strength imparted to the lines compensate for the added weight? Will the extra added strength carry the extra added weight? This question can be determined by examining the breaking length, which is the length of itself that a line will support. Table 22 shows the tensile strength in pounds and breaking length in feet of the untreated and treated lines before exposure; that is, the number of feet of line that will just support itself without breaking, calculated by dividing the weight per foot into the tensile strength in pounds. Similar figures are shown for the same lines after 30 days' exposure.

TABLE 22.—*Tensile strength and breaking length of all lines tested.*[1]

Symbol and treatment.	Freshly treated.		Exposed one month.	
	Tensile strength.	Breaking length.	Tensile strength.	Breaking length.
	Pounds.	*Feet.*	*Pounds.*	*Feet.*
A—White line, untreated control	39.3	32,600	30.4	25,200
B—Copper oleate 7 per cent	36.1	28,000	34.7	27,000
C—Copper oleate 7 per cent; 5 per cent oil, 1–1000 cresol	35.5	25,100	32.4	22,900
D—Copper oleate 11 per cent	36.1	23,300	37.6	24,600
E—Copper oleate 11 per cent, 2 per cent oil	31.4	21,000	35.0	23,200
F—Coal tar 50 per cent, benzol 50 per cent	35.4	17,900	44.6	22,700
G—Pine tar 50 per cent, benzol 50 per cent	35.2	19,500	44.4	24,500
H—Coal and pine tar 25 per cent each, benzol 50 per cent	37.4	21,800	48.6	28,300
I—Quercitron and potassium bichromate	39.3	28,100	39.2	28,000
J—Petroleum product No. 1	39.0	21,700	44.8	25,300
K—Waterproofing material	43.9	27,400	48.9	30,400
L—Dutch method	38.6	23,300	39.9	23,600
M—Copper oleate 7½ per cent	34.2	27,300	36.2	28,900
N—Copper oleate 12 per cent, 5 per cent oil, 1–1000 cresol	33.2	25,300	35.2	26,900
O—Copper oleate 12½ per cent	33.6	25,000	36.6	27,300
P—Copper oleate 12½ per cent, 5 per cent oil	36.3	26,200	37.2	26,900
Q—Copper paint No. 1	41.5	18,500	41.0	18,200
R—Copper paint No. 2	42.7	14,300	47.3	15,800
S—Gilsonite	35.5	21,500	28.2	15,700
X—Petroleum product No 2	32.9	20,400	35.0	21,700
Y—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent	35.0	17,400	44.5	22 300
Z—Copper oleate followed by coal tar	36.0	17,600	40.0	19,400
AA—Copper oleate 15 per cent	38.0	25,700	40.0	27,000

[1] The figures herein are averages from all the series studied.

It will be seen that those lines treated with tar or copper paint are of high tensile strength, especially after 30 days, yet the breaking length, which takes added weight into account, is comparatively low. Unexposed, untreated cotton line has a breaking length of 32,600 feet. If the increased strength of the line caused by application of tar and copper paints were proportional to the increased weight, the breaking length should be at least equal to that of the untreated lines, 32,600 feet. It is seen that this is not true for any of the preservatives when freshly applied. After a month's exposure many of the lines, such as tar, show an improvement, because of increasing binding on the fibers in comparison with the white line, which begins to weaken very soon. The copper oleates here show up well, while the copper paints, by their excessive weight, give poor results.

It can be concluded from this section of the paper that weight is an important factor in net preservation; that although some preservatives, like tar and copper paint, increase the tensile strength of lines by binding the fibers together, this increase of strength does not compensate for the increased weight imparted to the lines. It may also be concluded that tar increases weight markedly and so does copper paint. Copper oleate and the tanning methods are best in this particular, while the petroleum products and gilsonite are intermediate.

SHRINKAGE CAUSED BY APPLICATION OF PRESERVATIVES.

Many substances applied to lines as preservatives cause some shrinkage. As stated in connection with the description of the experiments, the samples were always measured to length while under a strain of 2 kg. (4.4 pounds). The standard used was a steel tape 50 feet long. The measurements, being made before and after treat-

ment, revealed, by difference, any change in lengths of the lines. Table 23 exhibits the results so obtained, which are also shown graphically in Figure 32.

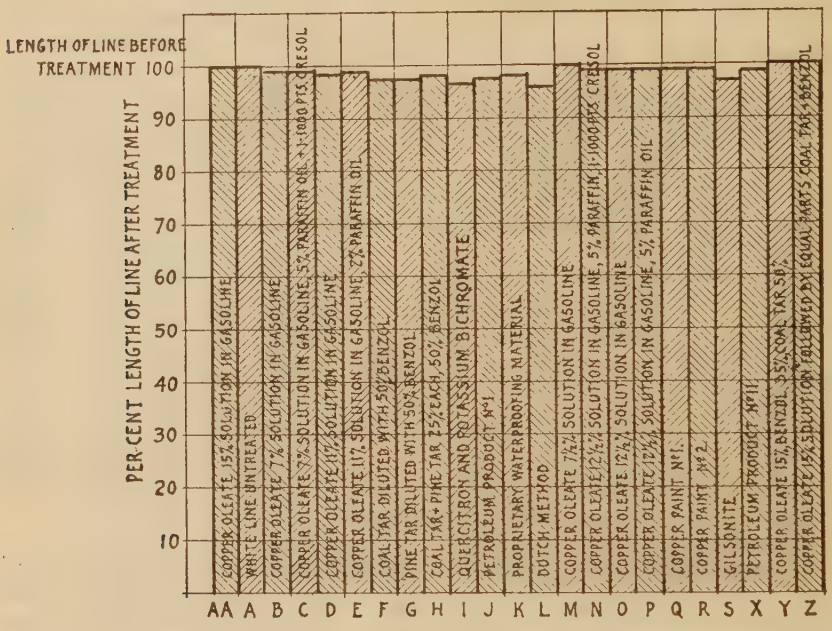
LENGTH OF LINE BEFORE TREATMENT 100
PER CENT LENGTH OF LINE AFTER TREATMENT
90
80
70
60
50
40
30
20
10
COPPER OLEATE 15% SOLUTION IN GASOLINE
WHITE LINE UNTREATED
COPPER OLEATE 7% SOLUTION IN GASOLINE
COPPER OLEATE 7% SOLUTION IN GASOLINE, 5% PARAFFIN OIL + 1-1000 PTS. CRESOL
COPPER OLEATE 11% SOLUTION IN GASOLINE
COPPER OLEATE 11% SOLUTION IN GASOLINE, 2% PARAFFIN OIL
COAL TAR DILUTED WITH 50% BENZOL
PINE TAR DILUTED WITH 50% BENZOL
COAL TAR + PINE TAR 25% EACH, 50% BENZOL
QUERCITRON AND POTASSIUM BICHROMATE
PETROLEUM PRODUCT N°1
PROPRIETARY WATERPROOFING MATERIAL
DUTCH METHOD
COPPER OLEATE 7½% SOLUTION IN GASOLINE
COPPER OLEATE 7½% SOLUTION IN GASOLINE, 5% PARAFFIN (1-1000 PTS CRESOL
COPPER OLEATE 12½% SOLUTION IN GASOLINE
COPPER OLEATE 12½% SOLUTION IN GASOLINE, 5% PARAFFIN OIL
COPPER PAINT N°1.
COPPER PAINT N°2.
GILSONITE
PETROLEUM PRODUCT N°II
COPPER OLEATE 15% BENZOL 35% COAL TAR 50%
COPPER OLEATE 15% SOLUTION FOLLOWED BY EQUAL PARTS COAL TAR & BENZOL
AA A B C D E F G H I J K L M N O P Q R S X Y Z

FIG. 32.—Shrinkage of cotton lines caused by one application of the various preservatives.

TABLE 23.—*Shrinkage of cotton lines caused by a single application of each of the various preservatives.*

Symbol and treatment.	Per cent shrinkage.					
	Washington.	Key West.	Beaufort.	Woods Hole.	Put in Bay.	Average.
B—Copper oleate 7 per cent	0.6	1.4	.....	.....	.....	1.0
C—Copper oleate 7 per cent; 5 per cent oil, 1-1000 cresol	.6	1.4	.....	.....	.....	1.0
D—Copper oleate 11 per cent	1.4	2.1	.....	.....	.....	1.7
E—Copper oleate 11 per cent, 2 per cent oil	.8	1.9	.....	.....	.....	1.3
F—Coal tar 50 per cent, benzol 50 per cent	2.1	1.4	2.9	.....	.....	2.1
G—Pine tar 50 per cent, benzol 50 per cent	1.9	.9	2.9	.....	.....	1.9
H—Coal tar and pine tar each 25 per cent, benzol 50 per cent	1.4	2.2	2.4	.....	.....	2.0
I—Quercitron and potassium bichromate	2.4	5.2	3.5	.....	.....	3.7
J—Petroleum product No. 1	2.6	2.6	2.4	.....	.....	2.5
K—Proprietary waterproofing material	2.1	2.1	.....	.....	.....	2.1
L—Dutch method	2.4	2.4	3.2	3.5	3.5	3.0
M—Copper oleate 7½ per cent	.....	.....	.1	.....	.....	.1
N—Copper oleate 12½ per cent, 5 per cent oil, 1-1000 cresol	.....	.....	.4	.....	.....	.4
O—Copper oleate 12½ per cent	.....	.....	1.1	.....	.....	1.1
P—Copper oleate 12½ per cent, 5 per cent oil	.....	.....	1.1	.....	.3	.7
Q—Copper paint No. 1	.....	.....	2.5	.7	.2	1.2
R—Copper paint No. 2	.....	.....	.3	.83	.....	.4
S—Gilsonite	.....	.....	2.7	.....	.....	2.7
X—Petroleum product No. 2	.....	.....	1.1	1.1	.8	1.0
Y—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent	.....	.....	.....	.4	.4	.4
Z—Copper oleate followed by coal tar	.....	.....	.....	.4	.4	.4
AA—Copper oleate 15 per cent	.....	.....	.....	.0	.0	.0

The results given are for only one application of the preservative. In practice, of course, some preservatives are repeatedly applied. Tar, copper paint, etc., can not well be applied repeatedly, because the accumulating substance increases weight and stiffness too much. Tanning materials, however, can be repeatedly applied, and it is just these that produce the greatest shrinkage, even on first application. This shrinkage is to be expected, for hot water is used in applying them. With repeated application, shrinkage becomes a rather serious objection to tanning extracts. The copper oleate, being applied cold in gasoline, produces very little shrinkage. In general, however, one application of any of the preservatives produces little shrinkage. On linen lines none of the preservatives used caused any measurable shrinkage.

TIME AND LABOR REQUIRED TO APPLY PRESERVATIVES.

These factors are, of course, of great importance. Where two preservatives are of the same value in all technical particulars, the one which is less expensive to apply is preferable. It sometimes happens that on off days the fisherman's time is worth little if it can not be employed on his nets and boats, and in large organizations the employees are sometimes without important work to do. In such cases the cost of material is the principal cost of preservation. The cost of copper oleate will be considered elsewhere.

The time required to apply the several preservatives and for the treated nets to dry may be expensive, especially in busy seasons, when time employed on nets is just so much time taken from fishing.

Table 24 sets forth the time required to dry the several preservatives after they have been applied.

TABLE 24.—*Time required for application and drying of preservatives.*

Preservative.	Number of applications.	Total time required for drying.
Copper oleate	1	30 to 45 minutes.
Pine tar 50 per cent in benzol	1	10 to 12 minutes.
Coal tar and pine tar 50 per cent benzol	1	20 to 24 hours.
Coal tar 50 per cent benzol	1	24 hours.
Tanning materials:		
Quercitron and potassium bichromate	3	12 to 18 hours.[1]
Dutch method	3	Do.[1]
Gilsonite	1	24 hours.
Petroleum products	1	36 to 48 hours.
Copper paint No. 1	1	No drying required.
Copper paint No. 2	1	Do.
Copper oleate-tar combinations	1	20 to 24 hours.

[1] Requires from four to six hours for each application to dry.

COLOR IMPARTED TO LINES BY PRESERVATIVES.

All the preservatives studied change the color of the lines. Just what the value of color in a line is and what color and shade would be preferable we do not know. There is a large literature on the subject of color vision in fishes, but results by different observers are quite inconsistent. Still less do we know of the reactions of fish to colors that they may distinguish. However, since many people who are

interested in net preservatives have their own and very often decided, opinions on the subject, a statement of the colors produced follows:

Preservative.	Color of treated line.
Copper oleate	Apple green, sky blue, or strong brilliant green, depending on concentration of preservative.
Tar	Dark brown or black.
Copper paint	Dark coppery red.
Petroleum products	Black.
Gilsonite	Do.
Tanning materials:	
Quercitron and potassium bichromate.	Brown.
Dutch method	Dark brown.
Copper oleate and tar combination	Dark brown or black.

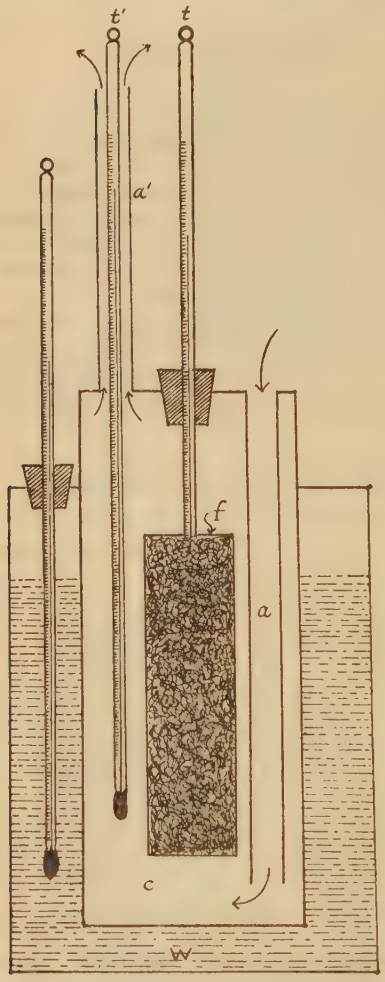

FIG. 33.—Apparatus used in testing the preservatives for tendency toward spontaneous heating.

SPONTANEOUS HEATING.

Spontaneous heating is commonly said by fishermen and others to cause the nets to rot. This heating is often attributed to the substance with which the nets are preserved. Experiments along this line have led the writers to suspect, however, that spontaneous heating of nets is caused by something other than the preservatives used.

APPARATUS USED FOR TESTING.

The apparatus used for these experiments (fig. 33) was made after the fashion of Mackey's spontaneous combustion tester. This consits, essentially, of a double-walled cylindrical water bath with a cover carrying two air circulation tubes, *a* and *a'*. The sample to be tested is placed in a cylindrical wire gauze or screen, *f*. A thermometer, *t*, extends into the sample. A second thermometer, *t'*, is suspended in the inner cylinder, *c*, through the air circulation tube *a'*. The water in the outer cylinder, *w*, is then heated to any arbitrary temperature and kept at that temperature for a period of three or four hours. The temperatures of the thermometers, *t* and *t'*, are noted at frequent intervals, and if the temperature of *t* in the sample exceeds that of *t'* in the air surrounding the sample, the difference may be taken as heat due to oxidation in the sample being tested.

LINSEED OIL.

Tests made were on cotton waste treated with the various preservatives studied. Two other tests were made upon samples of cotton waste that had been treated with linseed oil. Spontaneous heating is perhaps more likely to occur in the presence of linseed oil than of almost any other common substance. The tests with it were made, therefore, for the purpose of determining whether or not spontaneous heating would actually occur under the conditions set up for the experiments.

Twenty grams of cotton waste was moistened with 25 cc. of linseed oil and the waste allowed to dry somewhat and placed in the tester. The water was brought to boiling and the temperature of t and t' noted. The maximum temperature recorded by t was about 203° F. (95° C.). The temperature of the waste, shown by the thermometer t, rose at about the same rate as that of the surrounding air, shown by t'. When a temperature of 212° F. (100° C.) was reached, readings were made at intervals of one minute. The temperature rose 1, 1½, and 2° per minute up to about 266° F. (130° C.), when the differences became gradually larger, reaching a maximum between 300 and 345° F. (149 and 174° C.), when the differences were 14° F. (8° C.) per minute. The increments per minute then became gradually smaller, and a brown gas or smoke was noticeable above 368° F. (187° C.). The maximum temperature obtained in this experiment was 419° F. (215° C.). The waste was scorched to a brown color. The experiment with linseed oil was repeated with the same results as described in the preceding paragraph.

A third test with linseed oil was made but differed from the first two in that the temperature of the water in the outer jacket was maintained at 122° F. (50° C.) instead of 212° F. (100° C.). This temperature was held for about four hours, but the temperature of the waste saturated with linseed oil did not rise above that of the air surrounding it—about 113° F. (45° C.). It may therefore be concluded that a temperature higher than this is necessary to kindle spontaneous heating of linseed oil.

COPPER OLEATE.

A sample of copper oleate taken from the batch before it was blown was dissolved in benzol. Cotton waste was saturated with this benzol solution and allowed to dry, after which it was placed in the tester and the temperature of the water in the outer jacket brought to 212° F. (100° C.). This temperature was maintained for a period of three hours. The maximum temperature reached in the inner chamber was 194° F. (90° C.). The maximum temperature of the waste was also 194° F. (90° C.), proving that there was no elevation of temperature in the waste caused by the unoxidized copper oleate. This experiment was repeated under like conditions and the same results obtained as in the first case. Two other samples of waste that had been saturated with a benzol solution of the finished or oxidized copper oleate were tested in the same manner as described for the unoxidized samples. The maximum temperature obtained in each of these was 194° F. (90° C.), both in the sample of waste and in the air surrounding it.

The results obtained in all four of the above experiments would seem to indicate that there need be no fear of spontaneous heating of nets treated with copper oleate, either oxidized or unoxidized.

OTHER PRESERVATIVES.

Creosote oil: The substance as previously described as being used for a lubricant in the manufacture of copper oleate.

Heavy coal tar: A road tar diluted with an equal volume of benzol in order to thin it sufficiently for application.

Pine tar: Ordinary wood tar, thinned with an equal volume of benzol.

Light coal tar: A thin crude coal tar, containing all the substances found in crude coal tar with the exception of water and benzol.

Copper paint No. 1: A copper paint used as a net preservative.

All of the above products were tested by saturating cotton waste with each and placing it in the tester. In no case was there any evidence of spontaneous heating. The maximum temperature noted at any time in the air surrounding the sample was 203° F. (95° C.). Observed fluctuations in the temperature were in all probability due to air currents. At no time was the temperature of the waste over 200° F. (93° C.). The major portion of the time it was between 190 and 197° F. (88 and 92° C.). The water in the outer jacket was kept at boiling.

EFFECT OF HEAT ON COTTON LINES.

The question may here be raised as to how much heating is necessary to cause noticeable deterioration of the line. In order to answer this question, the following experiments were carried out:

Samples of No. 24 cotton line were heated in an electric oven in dry heat. One sample was heated for a period of two hours at a temperature of 212° F. (100° C.), another for two hours at 257° F. (125° C.), and a third for two hours at 302° F. (150° C.). These samples were subjected to tests for tensile strength and showed no appreciable weakening due to the heating. The sample that had been heated to 302° F. (150° C.) was slightly browned or scorched in appearance but was fully as strong as any of the other samples.

Other samples of the same kind of twine were heated in steam. One sample was heated with steam at 212° F. (100° C.), another at 239° F. (115° C.) under 10 pounds steam pressure, and a third at 257° F. (125° C.) under 20 pounds steam pressure. All samples were heated for two hours. Tests of tensile strength were also made on these lines, and again there was no noticeable difference between the lines that had been heated and those that had not.

The results of these experiments seem to indicate that a temperature much higher than any to which fish nets or lines are ordinarily subjected would have to be reached before any noticeable weakening of the threads would take place from the heat alone.

DISCUSSION OF RESULTS.

That some kind of heating occurs in nets in use seems certain. Since it is shown here that even linseed oil must be artificially heated to a comparatively high temperature before it continues to heat

spontaneously, it seems necessary to discover some factor other than those that entered into the experiments to account for spontaneous heating of nets. In the case of fish nets, water, fish blood, slime, and fish oil, and also sunlight, must be taken into account. Bacterial decomposition might well cause an initial elevation of temperature, but it seems likely that the activities of the bacteria would be arrested and the bacteria killed before a temperature would be reached sufficient to kindle spontaneous heating of the oil. It should also be pointed out, as casting doubt on the belief that spontaneous heating commonly damages nets, that the high temperatures to which lines were experimentally exposed without damage would probably never be reached spontaneously.

It may also be that the damage done to nets by spontaneous heating is of the nature of supposition without foundation. That nets heat may be a fact, that they rot is certainly a fact, but that the one causes the other does not necessarily follow. Other and more widespread beliefs than this have turned out to be erroneous. Further investigation of the subject of spontaneous heating will be necessary before positive conclusion can be reached.

GENERAL CONSIDERATION OF VARIOUS PRESERVATIVES IN LIGHT OF DATA PRESENTED.

Data have now been presented concerning the effects of 23 preserving materials (or combinations and variations thereof) on cotton lines, and four on linen lines, with data on the untreated lines as controls. The data concern effects of weather conditions at Washington, D. C.; the sea water at Key West, Fla., Beaufort, N. C., and Woods Hole, Mass.; and fresh water at Put in Bay, Ohio, as compared with treated but unexposed lines held as controls. In all, 393 samples were measured to length, weighed, treated, measured and weighed a second time, exposed to the elements, and upon return were tested for tensile strength, wearing quality, and stiffness, and notes were taken on fouling, color imparted, and time required for treatments to dry. Where so many data are presented, bearing in so many tangled ways on the practical choice and improvement of preservatives, it will require close study to draw useful and reliable conclusions. All the more so, in that the requirements of nets for different classes of service are markedly different. The different preservatives will now be considered and discussed separately.

TAR.

Tar is the most commonly used preservative for fish nets in the United States. Coal tar is used more than pine tar; sometimes the two are mixed. They are usually applied hot, often in a metal vessel by direct heat from a fire, sometimes by the use of steam. The direct heat process applies tar very heavily to lines, stiffens them, and increases weight greatly. Steam tarring applies tar to a much lighter extent, sometimes scarcely more than coloring the lines. In the present experiments coal tar, pine tar, and a mixture of equal parts of the two were studied. The tar was diluted by the addition of an equal volume of benzol and applied cold.

COAL TAR.

The coal tar used was the 270° F. fraction, a thick, black, sirupy liquid. It contains many things, including creosote or the cresols, that are highly antimicrobic. Under conditions of exposure to weather it protects the lines well. At Key West, in sea water, it showed a good preserving effect on tensile strength. At Beaufort it held the lines in good condition for about two months, after which time a rapid deterioration took place. This, it is assumed, is accounted for by the fact that the creosote present at first preserves the lines, but when it has dissolved, the lines are no longer protected. In ability to resist mechanical wear coal tar is at first very good, but as the lines stiffen and weaken on exposure this quality rapidly disappears. Tar greatly stiffens the lines. Where an untreated cotton line swings 40 to 50 times, a tarred line swings only about 15 to 20 times. Tar also increases the weight of lines, under conditions of application herein described, to the extent of about 50 to 70 per cent.

There is a noticeable increase in strength in tarred lines over the white lines, to which it is applied. This increase in strength, caused by a cementing of the fibers, is not sufficient to compensate for the increase in weight. The breaking length of an unexposed tarred line is less than that of the white line.

In resistance to the accumulation of fouling by marine growth tar is poor, and the time required to dry the applied tar is 12 hours or more. Tar is cheap in material but is laborious and messy to apply. It colors the nets dark brown or black.

Coal tar is suitable as a preservative for heavy nets, and when applied in concentration is much better than nothing on two months' continuous exposure, after which it is comparatively worthless. Fortified with copper oleate, coal tar was an extraordinarily good preservative. This will be referred to later.

PINE TAR.

Pine tar behaves very much like coal tar, running a close second to it in most respects. It does not preserve tensile strength quite so well, but, on the other hand, is not quite so stiffening. Little can be said in favor of pine tar as against coal tar.

MIXED TAR.

The tars mixed were also similar to the straight tars, the properties of the mixture being usually intermediate between those of the separate components.

TANNING OR BARKING.

Next to tarring barking is the commonest preservative treatment applied in this country. The use of bark is principally confined to gear that can not be tarred, such as gill nets and light seines. The barking process usually consists of dipping the net in a hot decoction of oak bark, cutch, or other tanning extract, in water. Since, in a previous paper (Taylor, 1921) it was shown that barking alone is of no noticeable value as a preservative (though the gear may be well

cleaned by it), experiments were restricted to the treatment of nets with a hot solution of quercitron, followed by a treatment with potassium bichromate, and the Dutch method. This latter method consists of treating the net with quercitron and following with a solution of 1 per cent copper sulphate in water, with 3 per cent of stronger ammonia water added. The experiments with quercitron, followed by potassium bichromate, were made in order to determine the effect of copper by comparison with the Dutch method.

Both tanning methods color the lines brown and by making them harsh greatly impair their ability to withstand mechanical wear or abrasion. Also, in their effect on stiffness, there is little difference, both stiffening the lines more than copper oleate but less than any of the other preservatives. They also shrink the lines more than any other preservative.

QUERCITRON AND POTASSIUM BICHROMATE.

Where the two methods begin to differ is in actual preserving effect on exposure to water, as shown by the tensile strength tests and also the wearing tests. The lines treated by quercitron and potassium bichromate at all places where tested did not last any longer than the untreated cotton lines. This method was therefore omitted from consideration in the later series.

THE DUTCH METHOD.

This method shows much merit. In the Key West, Beaufort, and Woods Hole series—that is, in all the sea-water tests—it had a preserving effect, as shown by tensile strength measurements, at first intermediate between copper oleate and tar. At the end it was still intermediate, though the copper oleate and tar had changed places. The order of tensile strength at first was tar, Dutch method, and copper oleate; later, copper oleate, Dutch method, and tar. In addition to its effect on tensile strength, the Dutch method also prevented fouling almost entirely.

On linen lines in sea water, where these two methods were also tried, the only preservatives worth considering were copper oleate and the Dutch method; quercitron and potassium bichromate did not show any preserving effect. The Dutch method and copper oleate both preserved to about the same extent at Beaufort, the lines lasting about four months' continuous exposure. At Woods Hole copper oleate was considerably better than the Dutch method, though the Dutch method showed merit.

In fresh water at Put in Bay the results were somewhat surprising. The Dutch method gave excellent results with cotton, easily outstripping copper oleate as far as tensile strength is concerned.

The linen lines treated by the Dutch method lasted only 60 days, while those treated with copper oleate lasted 90 days and were stronger than the linen lines preserved by the Dutch method.

As appearances now stand, the Dutch method in fresh water and for cotton lines is best; for linen lines in fresh water, copper oleate excels. It must be borne in mind, however, that only one series of experiments has been conducted. Before these conclusions are entirely trustworthy it will be necessary to carry out many more tests.

In salt water the Dutch method proved itself to be a very good preservative, but not the best. Lines preserved by it are strong, light, flexible, but wear easily from mechanical abrasion and shrink considerably, and the method is somewhat troublesome of application. Since the quercitron and potassium bichromate method and the Dutch method are similar, except for the absence of copper from the one and the presence of it in the other, it is clear that the preserving effect of the Dutch method lies in the copper and not in the tanning.

COPPER PAINT.

This material, long used for the bottoms of boats and ships to prevent the entrance of marine borers and to prevent also the attachment of fouling by barnacles and other growths, has been introduced only recently as a preservative of fish nets. The two commercial samples tested in these experiments are regularly sold for the purpose. One (Q) is a product prepared for fish nets by a considerable thinning. It contains much less copper oxide than the ship's paint. Accordingly, its properties that depend on body—that is, stiffness and weight—are somewhat less extreme than those of the straight ship's paint (R), the other sample tested. This latter contains very much more copper. It stiffens lines and increases their weight more than the other copper paint. The copper oxide present gives to lines treated by either of these paints a harshness that greatly reduces the wearing quality of lines treated by it. It is in this particular that they are at a great disadvantage when compared with other preservatives. They cause very little shrinkage but increase the weight from 60 per cent (Q) to 125 per cent (R). They both impart to nets the familiar reddish or coppery color that is seen on ships' bottoms painted with them. They are expensive but are not very troublesome to apply, as the nets are to be put into service in water without waiting to dry.

Both copper paints proved themselves to be most excellent preservatives of tensile strength under all conditions tested, both in salt and fresh water, being usually the strongest lines of all after exposure. They add something to the tensile strength of unexposed lines, but this increase is not sufficient to compensate for the added weight, as shown by the breaking length data. R, containing as it does a larger proportion of copper, is more effective under very severe conditions than Q, which contains less copper. When compared with the lines treated with copper oleate, which contained very much less copper, it appears that the large deposits of copper in the paints are unnecessary. Copper paints entirely prevented fouling in all the experiments.

In summary, copper paint is an excellent preservative of tensile strength and in preventing fouling, but is seriously lacking in wearing quality. It stiffens the lines and increases their weight and is decidedly expensive. It is unsuitable for gill nets and light seines.

PETROLEUM PRODUCTS.

These two materials, J and X, submitted for test, are prepared from petroleum from the Western States. They are black tarry liquids, J being heavier than X. X was prepared thin so as to be suitable for gill nets. They impart to the line a brown color, penetrate well, and as far as appearances go might readily be taken as good substitutes for

tar. In the trials, however, they fail to show any preserving quality worth considering. The tensile strength of lines treated by them rapidly diminishes on exposure, the stiffness is greatly increased, and the wearing quality, while good in the unexposed lines, rapidly disappears on exposure. The failure of these materials was equally rapid on cotton and linen lines.

GILSONITE.

This material, also called Uintaite, coming as it does from the Uinta Mountains of Utah, is an asphalt, similar to Trinidad asphalt. It is sold under a proprietary name as a net dip, and this proprietary product was the one tested in this work. It is a black sirupy liquid of a bituminous odor. When applied to cotton twine, it dries in about 24 hours, leaving the lines colored dark brown or black and of a stiffness as great as that produced by tar or copper paint. It increased the weight of No. 24 cotton twine when dipped 48 per cent, which is similar to the increase caused by tar.

As might be expected from the results already given, which show that mere waterproofing or covering lines is not in itself adequate to preserving them against deterioration on exposure, gilsonite fails to show any preserving effect. At Beaufort, where it was exposed, it was little better than no preservation as far as tensile strength was concerned. In resistance to mechanical wear gilsonite compared well at first with other preservatives, but this resistance soon disappeared on exposure of the samples. This substance, if fortified with copper oleate or some other toxic material, might be effective; but if it costs much more than tar, little if any advantage would be gained by substituting it for tar. Because of general failure and disintegration of lines treated by it gilsonite may be dismissed as of no value as a net preservative.

COPPER OLEATE.

In our experiments this substance is tested for the first time as a net preservative. It has been tried in various concentrations and combinations, and, as far as our experiments go, it shows characteristics that should make it valuable for preserving nets. If tensile strength of lines after exposure is alone taken as a measure of its preserving effect, copper oleate gave good results, though not always the best. In the Key West series it kept the lines up to their original strength for four and one-half months. At Beaufort the only preservatives that resisted six months' exposure were copper oleate, copper paint, and the Dutch method. Because of a binding effect on the fibers the tensile strength of the lines treated with copper paint was greater than that of lines treated with copper oleate. At Woods Hole again all those lines that endured six months had copper in some form in them. Those preservatives that contained a protecting body in addition to the copper lasted better than those treated with copper oleate alone. At Put in Bay in fresh water copper oleate alone did not give encouraging results, but combined with tar as a binder it gave excellent results. The copper oleate without binder seems to disappear from the lines rather rapidly in the fresh water of Lake Erie. In none of the foregoing experiments was copper oleate applied a second time to the sample. The amount of copper per yard of line was very small in

comparison with that in lines treated with copper paint, yet in preserving effect it occupied second place when it did not occupy first. In the Key West and Beaufort series, where different concentrations (7, 7½, 11, and 12½ per cent) were tried, solutions of copper oleate in gasoline, the higher concentrations, gave in every case better results. The addition of a small quantity of cresol effected no improvement, but the small quantity of oil seemed to increase the preserving effect. It is probable, therefore, that still higher concentrations than we used or repeated applications of copper oleate will give even better results and should equal any other preservative tried.

Copper oleate does not stiffen lines to which it is applied to an objectionable degree. In fact, it appears to be quite suitable for gill nets and other soft gear, where flexibility is essential. Lines treated with it made about three times as many swings, acting as pendulums, as lines treated with tar. The weight imparted to lines by the application of copper oleate is insignificant, being only about 16 per cent of the original twine. In these two particulars—that is, flexibility and weight—copper oleate greatly excels tar and copper paint. In ability to withstand mechanical wear, lines treated with copper oleate are better than any other treated lines tested. In this particular, also, it is far ahead of copper paint, which causes excessive wear.

Copper oleate prevented the attachment of marine growths to the lines exposed at all places, in this particular being equaled only by copper paint. Copper oleate when used alone, dissolved in gasoline and with or without oil, imparts to the lines a color that varies between azure and green as concentration varies. This color is said by some to be desirable. Japanese fishermen have introduced in the northwest the practice of dying green their gill nets used for salmon. The acceptability to different fishermen of the color imparted by copper oleate will be greatly influenced by their customs and their notions of fish behavior.

In case of application and time required to dry copper oleate is equal to any other preservative tested. When dissolved in gasoline or benzol in the proportion of 1 to 2 pounds of copper oleate to 1 gallon of solvent, the lines or nets need only be dipped in it and spread out to dry. Drying requires about one-half hour for cotton lines and two or three hours for linen or hemp. Applied in gasoline with a little mineral oil, then, copper oleate answers well all the principal requirements of a good net preservative. When copper oleate alone dissolved in benzol is applied to cotton twine, the copper oleate seems to creep to the surface of the twine as the solvent evaporates. The addition of about 1 pound of mineral oil or creosote to each 10 pounds of copper oleate prevents this creeping. Creosote seems preferable to oil as being cheaper and in possessing a toxicity of its own.

The combination of copper oleate and tar preserves the nets better than either copper oleate or tar alone. After six months' exposure in both fresh and salt water the samples of cotton line preserved with these combinations were equal in strength to the original unexposed samples. It made little difference whether the copper and tar were applied separately, or mixed. This being so, the choice would be the mixture that would require less labor in being applied. This combination is similar to copper paint in preserving effect and to

tar in weight and stiffness. In wearing quality it greatly excels copper paint. It would be a suitable preservative for heavy gear subject to continued severe exposure, such as traps and pound nets. Directions for applying this combination are as follows:

Dissolve 1 pound copper oleate in 1 gallon of benzol (gasoline is not suitable for this purpose). Stir in, cold, 1 gallon of coal tar, more or less, according to the stiffness and weight that is allowable. Dip the net in this combination cold and dry. Avoid fire.[4]

CHEMICAL PROPERTIES AND MANUFACTURE OF COPPER OLEATE.

Cupric oleate Cu $(C_{18}H_{33}O_2)_2$ is a green substance of the consistency of beeswax, insoluble in water, soluble in alcohol, ether, benzol, gasoline, carbon tetrachloride, turpentine, oils, etc., forming emerald green solutions. It contains, on the basis of the formula given, 10.15 per cent copper, by weight, though the percentage of copper in commercial preparations may vary between wide limits. It has a metallic coppery taste and is poisonous when taken internally, though external exposure to it is apparently harmless.

Copper oleate may be made in a number of different ways. It is precipitated when sodium oleate and any soluble copper salt are brought together in aqueous solution. When prepared in this way, it is gummy and contains much water that is removed only with difficulty. Cupric oxide dissolves in hot acid with formation of copper oleate and water, but it is difficult or impossible to carry the reaction to completion. Copper acetate and oleic acid combine at an elevated temperature, whereby copper oleate is formed and acetic acid driven off. The latter may be condensed and recovered. This method produces a good product, entirely soluble, but some acetic acid usually remains. Moreover, copper acetate is expensive.

The method employed in our production of copper oleate was to treat copper carbonate (containing also copper hydroxide) with oleic acid. In this reaction carbon dioxide and water are produced, and both are driven off by heat. Both reagents are obtainable in commerce in large quantities at a low price. The current (December 30, 1922) price of copper carbonate is 20 cents per pound, and oleic acid (the red oil of commerce) is 10 cents per pound. The exact procedure as followed in the laboratory in making this material is as follows:

Into a 5-gallon copper steam-jacketed kettle put 4 pounds of dry copper carbonate. Moisten this with enough red oil (about 1 quart) to make a paste; knead the paste with a wooden pestle until all lumps are crushed and the mass is of uniform consistency. Stir in more oil. As the oil is added large quantities of gas are generated, and constant stirring is necessary to keep the contents from running over the sides of the kettle. As the foaming subsides more oleic acid is put in until 15 pounds in all have been added. Steam is now cautiously admitted to the jacket, and with constant stirring the mass is kept from foaming over. A thermometer is kept in the mass. When the boiling point of water is reached, bubbles of steam escape rapidly. This bubbling may continue for two hours or more, until

[4] Net and twine manufacturers, or others who might be interested in the regular application of this combination, should take notice that continued breathing of the vapors of benzol are harmful, and workers should be protected accordingly by adequate ventilation of workrooms.

all the water is driven off, during which time the temperature does not rise far above 212° F. (100° C.). When bubbles of steam cease to escape, the temperature will rise slowly until 45 pounds' pressure of steam is maintained in the jacket, the copper oleate comes to a temperature of 257 to 268° F. (126 to 132° C.), and the mass is a thick green liquid. When this temperature is reached, an air hose nozzle is so placed that air is blown in and bubbles through the hot mass from the bottom. Stirring now helps to incorporate the air bubbles in the mass and to accelerate oxidation. As the mass absorbs oxygen, it becomes very viscid, so that a stick inserted in it and brought out carries a sticky bulk which in large part hangs without dropping. The blowing requires about one-half hour. The blowing of air is, of course, for the purpose of oxidizing the mass with as much oxygen as it will spontaneously absorb at this elevated temperature, so as to diminish the likelihood of spontaneous heating of fish nets to which it is applied.

When the consistency just described is reached, the batch is considered finished, a lot sample is taken, and to the batch is added the amount of oil necessary to prevent creeping. If oil is used, it should be mineral lubricating oil in the proportion of 3 pints for the batch as described. Later experiments, however, indicate that creosote answers the same purpose more cheaply and more effectively. Creosote is a good preservative itself; it prevents the copper oleate from creeping to the surface of lines and can be bought for 50 cents per gallon or less. If creosote is used, 1½ to 2 pints to the batch quantity described is sufficient. The creosote used in the work herein described has the following properties: A thin mobile brownish but rather transparent liquid; specific gravity, 980; smell, smoky. It is the grade used for preserving wood.

When the oil or creosote has been added and thoroughly mixed into the mass, the latter is poured into cans or other containers and set aside to cool. A record is kept of each batch, which is designated by number. If cans are used, they may be of the friction-top type. The contents of a 5-pound can will, when dissolved in 5 gallons of gasoline, treat between 50 and 60 pounds of cotton net. When dissolved in 2½ gallons of gasoline, it will treat 25 to 30 pounds of net with a comparatively heavy deposit of the preservative, suitable for severe conditions. For combining tar the contents of a 5-pound can are dissolved in 5 gallons of benzol and 5 gallons of coal tar are added and mixed, making about 10½ gallons of a preservative, suitable for traps and other gear, subject to the severest exposure. The nets are dipped in the mixture cold and are hung out to dry. Drying takes about 24 hours. It may also be applied separately to the lines, as will be described below, the lines then to be tarred in the usual way.

METHOD OF APPLYING COPPER OLEATE TO NETS.

The copper oleate as canned is dissolved in gasoline. If it does not already contain the oil or creosote, one of these must be added in the quantity indicated. The cold, waxy, copper oleate dissolves rather slowly in gasoline, but the can may be put in boiling water for a few minutes, until the copper oleate is liquefied; it then dissolves quickly. The gasoline solution should be contained in a metal vessel (a galvanized-iron washtub, for example); the net is dipped into this

mixture and hung (not piled) to dry. Any unused portion of the copper oleate in gasoline may be kept indefinitely in a tightly corked can, such as a 10-gallon oil can. For larger quantities a steel gasoline barrel is suitable. The treatment may be repeated as often as seems desirable without danger of injury to the twine.

GRADING THE SEVERAL MATERIALS AS ALL-ROUND PRESERVATIVES.

In the experimental part of this paper it has been shown that the several materials studied differ in value as net preservatives—in one particular respect one preservative may excel, in another some other preservative. The impression may have been given that in most respects copper oleate is best. But, just how much better is one preservative than another, considered generally? Some systematic and impartial method of attaching values to the different factors—such as tensile strength, stiffness, and wearing quality—by which to grade the several preservatives accordingly is desirable. Can we not derive a figure that is made up of the several values of tensile strength, wearing quality, flexibility, etc., that will give an indication of the all-round value of each preservative?

In deriving such a figure it is impossible to avoid making assumptions that are more or less arbitrary. It is also necessary to ignore the obvious fact that for different purposes and classes of nets the relative weights of the different factors are quite dissimilar. For example, in gill nets the necessity of flexibility absolutely dominates the choice of material and preservation, while in pound nets flexibility is of no great importance, but preservation of tensile strength, ability to withstand chafing or abrasion, and resistance to fouling by marine growths are decisive factors.

In selecting a suitable preservative, therefore, one can not avoid a consideration of the relative importance of the several factors for the particular purpose the net is intended to serve. Nevertheless, our new preservative, copper oleate, is proposed for all classes of nets. If it can make a good score in all or most of the several requirements that make it suitable for many different purposes, it is more desirable than a preservative that excels for some limited purpose and is useless for others.

The following method of grading the preservatives for all-round use on cotton lines involves the minimum number of arbitrary assumptions: (1) The breaking length of the treated line was first calculated; that is, the length of line that will just hold itself up. (2) This figure was then reduced to the same extent as the shrinkage was found to reduce the length of cotton lines on application of the preservative. (3) This figure was then multiplied by a factor that, in the case of white untreated line, brings the breaking length to 100. Thus, the samples were compared with white line as a standard of excellence. (4) The number of strokes on the wearing tester was multiplied by a factor that, in the case of white untreated line, brings the number of strokes to 100. Here, again, the samples were referred to white line as a standard. (5) The number of pendulum oscillations of the several samples (flexibility) was multiplied by a factor that, in the case of white untreated line, gives 100 oscillations. This factor is also referred to white line as a standard. We thus take into the reckoning tensile strength, increase in weight,

shrinkage, resistance to wear, and flexibility, and by multiplying each by a factor, that, in the case of white line, brings each figure to 100 we attach the same weight to the factors, and at the same time refer all samples to the one standard of excellence for fishing purposes, the new white line. The ideal preservative is that one that most closely keeps its twine like new white line for the longest time, and our composite score by its magnitude indicates the relative ability of the preservatives so to keep the lines. It was not practicable to include in the score resistance to fouling, because exact numerical expression for this factor was lacking. Allowance for it would raise the values for copper oleate and copper paint alike with respect to all the others, for only these two preservatives prevented fouling.

The new untreated, unexposed cotton line, No. 24, cable-laid, hard-finish, scored in the way described 300, or 100 for each of the three different factors, derived as follows:

Let

T=tensile strength in pounds of sample.

W=weight in pounds per 100 feet.

$\frac{T}{W}$=breaking length in hundreds of feet.

S_1=original length, in hundreds of feet, of sample before treating.

S_2=length, in hundreds of feet, of sample after treating.

$\frac{S_2}{S_1}\times\frac{T}{W}$=breaking length, in hundreds of feet, of sample after treating.

F=flexibility=number of swings of pendulum.

A=number of strokes on wearing machine.

For white line:

$\frac{100}{\frac{S_2}{S_1}\times\frac{T}{W}}=F_1$=the factor that brings the shrunken breaking length of white line to a value of 100. This white-line factor is used in bringing the shrunken breaking length of treated line to a common standard.

$\frac{100}{F}=F_2$=factor that brings the flexibility of untreated white line to a value of 100. This white-line factor is used for the treated line.

$\frac{100}{A}=F_3$=factor that brings the wearing ability of white line to a value of 100.

Then, the full score of any sample is the sum of the three separate scores, shrunken breaking length, flexibility, and wearing ability,

$$\frac{S_2}{S_1}\times\frac{T}{W}\times F_1+FF_2+AF_3.$$

In Table 25 are given the numerical values of the scores of all lines in the Beaufort and Woods Hole series. The same data are presented in graphic form for the several preservatives in Figure 34. It is seen that treatment by any preservative whatsoever causes a reduction in the score.

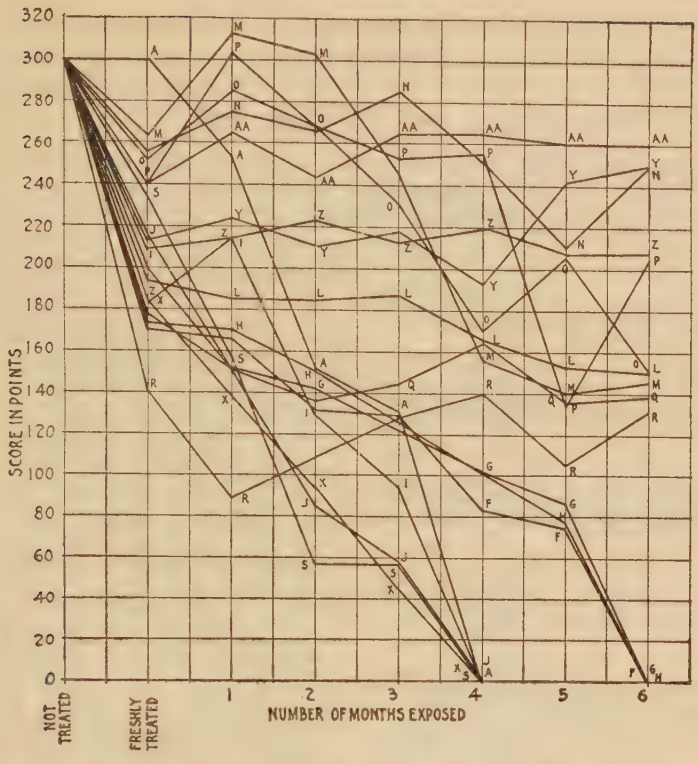

FIG. 34.—Scores of the several preservatives showing their relative values applied to cotton line, tensile strength, wearing quality, flexibility, shrinkage, and increase in weight considered. New untreated white cotton line is the standard, scoring 300.

TABLE 25.—*Scores of cotton lines at Beaufort, N. C., and Woods Hole, Mass.*

Symbol and treatment.	Tests.	Unexposed.	Number of months exposed.					
			1	2	3	4	5	6
A—White line, untreated control.	Breaking length	100.0	92.0	32.5	13.5	.....	.....	.....
	Wearing quality	100.0	19.8	5.1	2.7	.....	.....	.....
	Flexibility	100.0	140.0	114.0	115.0	.....	.....	.....
	Total	300.0	251.8	151.6	131.2	.....	.....	.....
F—Coal tar 50 per cent, benzol 50 per cent.	Breaking length	55.0	72.0	70.0	57.0	36.0	28.0	.....
	Wearing quality	55.0	48.5	16.6	32.2	9.7	4.2	.....
	Flexibility	60.5	46.5	46.0	40.0	39.0	43.5	.....
	Total	170.5	167.0	132.6	129.2	84.7	75.7	.....
G—Pine tar 50 per cent, benzol 50 per cent.	Breaking length	60.0	76.5	79.0	57.0	20.1	4.9	.....
	Wearing quality	45.0	40.0	27.6	21.2	16.2	.....	.....
	Flexibility	72.0	36.4	36.0	44.0	66.5	82.5	.....
	Total	177.0	152.9	142.6	122.2	102.8	87.4	.....
H—Coal tar 25 per cent, pine tar 25 per cent, benzol 25 per cent.	Breaking length	67.0	78.0	84.0	60.0	50.0	29.0	.....
	Wearing quality	47.5	48.5	30.4	26.1	12.3	2.8	.....
	Flexibility	58.5	43.5	36.0	40.0	39.8	46.5	.....
	Total	173.0	170.0	150.4	126.1	102.1	78.3	.....
I—Quercitron mordanted with potassium bichromate.	Breaking length	86.0	94.0	43.0	5.2	.....	.....	.....
	Wearing quality	14.3	12.7	.....	.....	.....	.....	.....
	Flexibility	109.0	108.0	87.0	89.5	.....	.....	.....
	Total	209.3	214.7	130.0	94.7	.....	.....	.....

TABLE 25.—*Scores of cotton lines at Beaufort, N. C., and Woods Hole, Mass.*—Contd.

Symbol and treatment.	Tests.	Unexposed.	Number of months exposed.					
			1	2	3	4	5	6
J—Petroleum product No. 1	Breaking length	66.5	69.5	41.0	15.0	.....	.....	.....
	Wearing quality	79.5	35.1	.....	.....	.....	.....	.....
	Flexibility	70.0	44.0	44.0	44.0	.....	.....	.....
	Total	216.0	148.6	85.0	59.0	.....	.....	.....
L—Dutch method, quercitron mordanted with ammoniacal copper sulphate.	Breaking length	71.5	75.0	71.0	66.5	44.0	29.6	28.5
	Wearing quality	13.4	16.1	18.8	26.4	18.2	4.5	3.3
	Flexibility	108.5	94.5	95.5	94.5	104.0	119.0	118.5
	Total	193.4	185.6	185.3	187.4	166.2	153.1	150.3
M—Copper oleate 7½ per cent in gasoline.	Breaking length	84.0	88.5	89.0	72.0	40.5	24.8	23.6
	Wearing quality	33.4	45.5	40.2	36.5	3.6	2.3	1.7
	Flexibility	146.0	179.0	174.0	137.0	112.0	113.0	120.0
	Total	263.4	313.0	303.2	245.5	156.1	140.1	145.3
N—Copper oleate 12½ per cent in gasoline, 5 per cent paraffin oil, 1–1000 parts cresol.	Breaking length	77.5	83.0	79.0	79.0	59.5	51.0	28.2
	Wearing quality	36.0	44.5	33.2	42.5	22.4	12.1	64.5
	Flexibility	143.0	148.0	154.0	165.0	170.0	152.0	158.0
	Total	256.5	275.5	266.2	286.5	251.9	215.1	250.7
O—Copper oleate 12½ per cent in gasoline.	Breaking length	77.0	84.0	91.5	68.5	48.5	52.0	20.0
	Wearing quality	54.0	54.0	40.5	35.0	11.4	13.6	1.4
	Flexibility	121.0	147.0	137.0	128.0	110.0	141.0	139.0
	Total	252.0	285.0	269.0	231.5	169.9	206.6	160.4
P—Copper oleate 12½ per cent in gasoline, 2 per cent in paraffin oil.	Breaking length	80.0	82.5	84.5	82.5	66.0	43.0	37.4
	Wearing quality	40.0	65.0	44.5	37.4	34.5	3.6	11.7
	Flexibility	120.0	155.0	139.0	134.0	156.0	85.0	156.0
	Total	240.0	302.5	268.0	253.9	256.5	131.6	205.1
Q—Copper paint No. 1	Breaking length	57.0	56.0	56.0	55.0	58.0	48.0	40.6
	Wearing quality	65.0	15.3	11.3	15.0	14.1	9.9	6.6
	Flexibility	75.5	80.0	69.5	75.0	93.0	79.0	92.0
	Total	197.5	151.3	136.8	145.0	165.1	136.9	139.2
R—Copper paint No. 2	Breaking length	44.0	45.0	48.5	48.5	67.0	40.5	43.2
	Wearing quality	25.0	6.6	5.0	5.2	3.9	4.4	4.1
	Flexibility	71.0	37.5	55.5	74.5	70.0	71.0	84.5
	Total	140.0	89.1	109.0	128.2	140.9	115.9	131.8
S—Gilsonite	Breaking length	66.0	48.0	14.4	6.4	.....	.....	.....
	Wearing quality	79.0	58.5	.....	.....	.....	.....	.....
	Flexibility	88.5	51.0	43.5	51.5	.....	.....	.....
	Total	233.5	157.5	57.9	57.9	.....	.....	.....
X—Petroleum product No. 2	Breaking length	63.0	74.5	27.2	14.0	.....	.....	.....
	Wearing quality	37.4	19.1	9.7	4.2	.....	.....	.....
	Flexibility	83.0	45.0	58.5	27.1	.....	.....	.....
	Total	183.4	138.6	95.4	45.3	.....	.....	.....
Y.—Copper oleate 15 per cent, benzol 35 per cent, coal tar 50 per cent.	Breaking length	53.5	66.0	64.5	72.5	65.5	76.5	71.5
	Wearing quality	76.0	84.0	79.5	76.0	51.0	32.4	36.8
	Flexibility	85.5	74.0	75.0	70.0	77.0	134.0	142.0
	Total	214.0	224.0	211.0	218.5	193.5	242.9	250.3
Z—Copper oleate 15 per cent in gasoline followed by coal tar.	Breaking length	54.0	57.0	58.5	72.0	59.5	74.5	66.0
	Wearing quality	64.0	84.5	70.5	64.5	36.0	39.0	44.5
	Flexibility	65.5	72.5	94.5	77.0	115.0	94.0	97.5
	Total	183.5	214.0	223.5	213.5	220.5	207.5	208.0
AA—Copper oleate 15 per cent in gasoline.	Breaking length	79.0	88.0	77.0	77.0	81.5	63.0	65.0
	Wearing quality	57.5	64.0	44.0	52.5	18.6	28.8	28.2
	Flexibility	104.1	112.0	123.0	137.0	166.0	170.0	169.0
	Total	240.6	264.0	244.0	266.5	266.1	261.8	262.2

The only lines that at any time make a higher score than white line are the line, M, treated with copper oleate, after the first and second month, and P, another line treated with copper oleate, after the first month. The Dutch method, L, makes a good score. The copper paints, Q and R, at first make a poor showing because of excessive weight and low wearing ability, but because of a good preserving effect they occupy a high place, compared with others, after three months. The tarred lines, F, G, and H, all make similar scores but are intermediate between the better and poorer preservatives. In Figure 35 these lines are grouped for a more convenient interpretation.

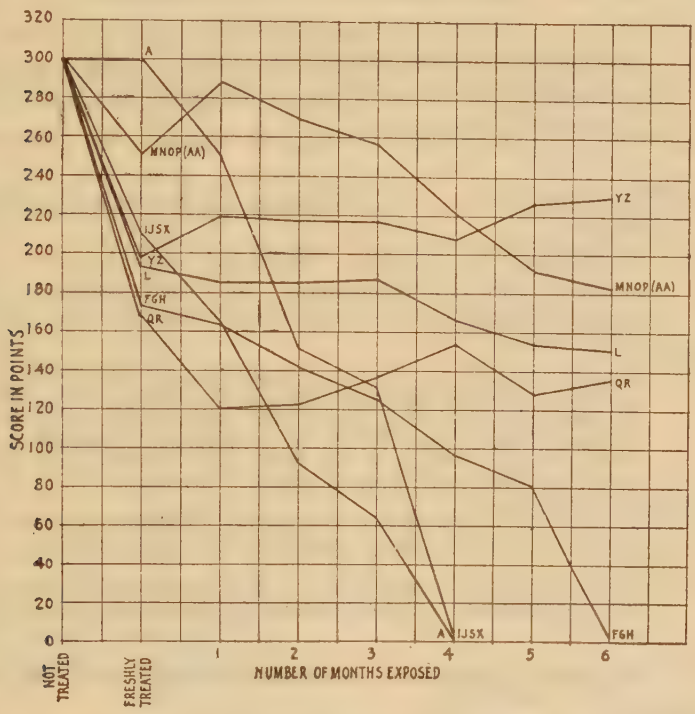

FIG. 35.—Scores of the preservatives shown in Figure 34, with the preservatives having a similar effect grouped.

The samples treated with copper oleate easily lead as all-round preservatives when rated by the method described, the copper paints and the Dutch method show merit, the tarred samples are somewhat better than nothing, and the quercitron and potassium bichromate method and three proprietary preservatives do not score at any point as high as the plain white line.

The striking fact, already mentioned, is again evident in this connection, that those preservatives that contain copper in some form deposited in the lines are best—copper oleate, the copper paints, and the Dutch method. It is plain that in the Dutch method copper is the active ingredient, for in the quercitron and potassium bichromate method the same tanning extract mordanted without copper is ineffective. Since copper seems essential in a net preservative, the form that

carries with it fewest incidental objections, such as stiffness, increase in weight, and wearing quality, is preferable. Copper oleate is undoubtedly best in all these particulars.

TABULAR SUMMARY.

For convenient reference and comparison a summary of the properties of the various preservatives is given in Table 26.

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TABLE 26.—*Summary of properties of net preservatives.*

Preservative.	Tensile strength.	Wearing quality.	Flexibility.	Shrinkage.	Increase in weight.	Fouling.	Time required for application.	Color.	Value as a preservative in fresh water.
Copper oleate without binder.	Causes immediate diminution by lubrication of fibers; thereafter tensile strength remains constant over long period; excellent preservative.	Preserves wearing qualities over long periods in salt water, but not in fresh water.	Flexibility considerably increased immediately after treating; this flexibility decreases after two or three weeks to an equality with untreated line; twine remains soft and pliable; suitable for gill nets.	Shrinkage very small; causes about 0.5 to 1.5 per cent decrease in length after one application.	Increase in weight not great; average of all lines treated shows about 16.5 per cent gain in weight, as applied.	Very little fouling; a few barnacles were in evidence, but no hydroids or other growth appeared on 4 months' exposure.	Lines or nets can be treated in short time; should be immersed for 5 or 10 minutes and will dry in about one-half hour.	Color varies from a light green to a darker bluish green, depending upon concentration of the preservative.	Used alone on cotton lines it is not of much value; on linen line results are much better.
Tar (pine, coal, and mixed).	Immediate diminution of tensile strength followed by marked increase, which drops off after two months in salt water.	Very good on freshly treated lines but diminishes rapidly on being exposed; exposed lines not so good as copper oleate.	Very stiff; fewer oscillations of pendulum than any other preservative.	Shrinkage not great, but a little more than copper oleate; averaged 2.22 per cent on one application.	Increase in weight very high, especially in case of coal tar; average increase 56.8 per cent when applied from 50 per cent benzol solution.	Lines contained heavy growth of hydroids and barnacles.	Much labor and time required to treat line; from 24 to 36 hours required for drying.	Dark brown or black.	No experiments with tar alone have been made in fresh water.
Copper paint Nos. 1 and 2.	Slight immediate increase followed by marked increase, which remains quite constant even after long exposure; good preservative.	Poor resistance to mechanical wear.	Causes immediate stiffening, but not to as great a degree as tar; copper paint No. 1 remains fairly constant, while copper paint No. 2 continues to grow stiffer.	Very little shrinkage; about 0.5 per cent on one application.	Greatest increase in weight of all preservatives studied; copper paint No. 1, 65 per cent; copper paint No. 2, 127 per cent.	No fouling of any sort after 6 months' exposure.	Not much labor or time required; drying before use unnecessary.	Dark red.	Tensile strength undiminished at end of 6 months' exposure; no difference in behavior in fresh or salt water.
Petroleum product Nos. 1 and 2.	Very little immediate change; product No. 1 shows marked increase after a short time; product No. 2 shows little change; both decrease very rapidly on being exposed; poor preservative.	Product No. 1 when freshly applied resists mechanical wear better than any other preservative; product No. 2 resists wear only moderately well; about one-half as well as No. 1; on exposure both rapidly lose resistance to wear.	Causes considerable stiffening which increases for 3 or 4 weeks and then remains constant.	Shrinkage about 2 per cent on one application.	Increase in weight averages about 41.9 per cent.	Lines contained heavy growth of hydroids and barnacles; preservative seems to have no antifouling quality.	24 to 36 hours required for drying.	Black	No value as a preservative for fresh water.
Gilsonite	Slight immediate decrease followed by rapid decrease during time of exposure; poor preservative.	Resistance to mechanical wear very good when freshly treated, but this quality soon disappears when the line is exposed.	Causes a little immediate stiffening and grows gradually stiffer for about 4 weeks; about like tar.	do	Increase in weight 46 per cent.	Lines exposed for short time are laden with heavy growth of hydroids and barnacles.	Requires but little time to apply, but is rather slow drying; about 24 hours required.	do	Not tried in fresh water.
Tanning extract (quercitron) with potassium bichromate as a mordant (copper omitted).	No immediate change in tensile strength; little change noticed on Key West and air conditions lines, but strength decreased rapidly on Beaufort lines; poor preservative as used.	Very poor.	Flexibility of line little affected.	Considerable shrinkage as compared to most other treatments, this line showing 3.48 per cent decrease in length on one application.	Very little increase in weight; about 10 per cent.	Lines carried heavy growth of hydroids and barnacles.	Two treatments with the extract and one treatment with the mordant; about 24 hours required for entire process, including time of drying.	Brown	No experiments.
Dutch method	Practically no immediate change; experimental lines at all places endured 6 months with some tensile strength remaining; good preservative, especially for cotton lines.	Poor	Flexibility of line very little affected.	Shrinkage comparatively large, as with most preservatives applied hot; decrease in length 3.6 per cent on one application.	Increase in weight 20 per cent.	Not much fouling after 5 months' exposure in sea water at Beaufort, N. C.	Time required same as that of tanning extract listed above.	Dark brown	Better in fresh water than in salt water for cotton, but not as good as copper oleate for linen in fresh water.
Copper oleate-tar combinations.	Slight immediate decrease followed by marked increase which remains quite constant through long exposure; strength after 6 months unimpaired.	Is exceeded only by the white untreated line; wearing qualities excellent even after long periods of exposure.	Depends on percentage of tar used; where 50 per cent of tar is used the flexibility is about equal to that of copper paint; after 2 or 3 months' exposure it becomes very much more flexible than copper paint.	Shrinkage very little, about 0.5 per cent.	Great increase in weight; about 60 per cent.	No fouling in any experiments.	24 to 30 hours	do	Preserving effect on 6 months' exposure same for fresh and salt water.

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